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TREE-RING COLLECTIONS IN THE NORTHERN GREAT PLAINS IN 1991 AND 1992

by
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Tree-Ring Collections

in the Northern Great Plains in 1991 and 1992

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An Appendix to

Final Project Report:

National Science Foundation Grant No. ATM-9016901
and
National Science Foundation Grant No. ATM-9017155

April 10, 1995

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Preface

This tree-ring data described in this report were collected as part of a collaborative research project by three institutions: the Rocky Mountain Forest and Research Experiment Station, South Dakota School of Mines Campus (RMFRES); the Laboratory of Tree-Ring Research, University of Arizona (UATRL); and the Institute of Atmospheric Sciences, South Dakota School of Mines and Technology (SDSM&T). Shelly Deisch, Steve Denison, Helen Fitting, Jeff Baumberger, Scott Gamo, R. Homann and Jody Haversak, of RMFRES, assisted greatly in the field collections. Wanmei Ni, Thomas P. Harlan, Connie Woodhouse, and Elizabeth Fairchild-Parks, of the UATRL, prepared, crossdated and measured the wood samples. Arthur T. DeGaetano, James R. Miller, Jr., Matt Bunkers, and Dave Priegnitz, of SDSM&T, offered much useful advice on climatological aspects of the study. The collections would not have been possible without the enthusiastic cooperation of ranchers, farmers, and other land owners, as well as the help of numerous foresters, biologists and other scientists from national forests and state and national parks.

Table of Contents

Preface ii

Table of Contents iii

List of Figures iv

List of Tables iv

Introduction 1

Methods 2

Collection and Processing of Tree-Ring Samples *2*

Standarization *2*

Modeling the Tree-Ring Response to Annual Precipitation *6*

Tree-Ring Collections **12**

Chronologies **18**

Summary Statistics *18*

Chronology Snapshots *22*

References **82**

Appendix A. Contents of Diskette **86**

Appendix B. Reno Gulch Standard Chronology -- 1281-1599 ..... **88**

List of Figures

Figure 1. Steps for conversion of ring-width series to chronologies 3

Figure 2. Diagram illustrating relationships among input, output and noise for model structures 9

Figure 3. Map showing locations of tree-ring site 13

Figure 4. Chronology snapshots (two-page, for each chronology) 27-81

List of Tables

Table 1. Information on Tree-Ring Sites 14-16

Table 2. Chronology Statistics 19-20

Introduction

Tree-ring research on drought history in the western United States began with a localized study of post oak (*Quercus stellata*) in Texas by Jacob Keuchler in the 1850s (Campbell 1949). More than half a century passed, however, before the climatological value of tree-ring analysis was firmly established (Douglass 1909, 1919, 1928). Regional climatological applications soon followed in various parts of the western United States (e.g., Stallings 1933; Weakly 1943; Jessup 1935; Keen 1937; Antevs 1938; Schulman 1956). The first such regional study in the Dakotas was a chronology of wet and dry years, 1406-1940, for east-central North Dakota from archaeological wood specimens and a "master" 373-ring stump of bur oak (*Quercus macrocarpa)* (Will 1946).

Schulman's (1956) pioneering field collections from 13 major river basins from west-central Mexico to western Canada were the starting point for the development of the present-day climatological tree-ring network in the western United States. The University of Arizona Laboratory of Tree-Ring Research (UATRL) set out in the early 1960s to re-sample Schulman's sites, augment those with new collections, and standardize the resulting data uniformly using modern statistical techniques. The resulting chronologies are described in volumes I-VI of *Tree-Ring Chronologies of Western America, Chronology Series I* (Laboratory of Tree-Ring Research 1972a, 1972b, 1973, 1974, 1975a, 1975b). The first modern Dakotas chronologies, collected by H.C. Fritts in the mid-1960s, are included in volume IV of the series. Volume IV lists three ponderosa pine (*Pinus ponderosa*) chronologies -- two from the southwestern corner of South Dakota (southern Black Hills) and one from the Rosebud Sioux Reservation in far south-central South Dakota. Three more chronologies were collected from the western Dakotas in 1980 by Thomas Harlan and David Meko, of the UATRL. These sites are near Custer, in the Black Hills of South Dakota; in the Slim Buttes of northwestern South Dakota; and near Amidon, in southwestern North Dakota. The chronologies were used in reconstructions of regional precipitation (Meko 1982; Stockton and Meko 1983), and in a larger-scale assessment of drought frequency in the Great Plains (Meko 1992).

This report describes a new set of tree-ring chronologies developed since 1991. The main objectives of the report are to (1) document the collections and methods of chronology development, (2) summarize the statistical properties of the chronologies and their component core-index series, and (3) assess the quality of the data for climatological application. The tree-ring data described in this report were collected primarily to improve the tree-ring resolution of drought frequency in North Dakota and South Dakota. These important grain-producing states have been visited by devastating multi-year droughts over the past century (Borchert 1950, 1971). General circulation models (GCMs) predict that summer soil moisture will dramatically decrease in the region as climate changes due to increasing greenhouse gases (Manabe and Wetherald 1986). Tree-ring data can be used to place such predictions in a context of several hundred years of natural climatic variability

Section 2 of this report describes the methods of field collection, chronology development, and assessment of the annual precipitation signal in the chronologies. Section 3 briefly describes the collection strategy and presents information on the 53 collection sites. Section 4 summarizes statistical properties of the resulting chronologies and the results of modeling of the chronology response to annual precipitation. Also in section 4 are individual two-page text and graphical summaries for each chronology, including a listing and time series plot of the standard chronology.

Computer files of ring-width measurements, site chronologies, and computer input-control files with sufficient information to enable an independent researcher to duplicate computation of chronologies from the original ring widths are available on diskette. Appendix A describes the files on the diskette. Appendix B contains a listing of the early part of the Reno Gulch, South Dakota, chronology, which is too long to fit the two-page summary format of section 4.

Methods

Collection and Processing of Tree-Ring Samples

Tree-ring core samples were collected using conventional methods (Stokes and Smiley 1968; Fritts 1976). Whenever possible, two cores were taken from several trees at a site, and trees were cored transverse to the slope of the ground at between waist-height and breast-height. Cores were stored in paper straws for transport to the University of Arizona Tree-Ring Laboratory (UATRL); there the cores were straightened if necessary by steaming and twisting, and were glued into grooved wooden core mounts. Samples were then surfaced with a razor blade and varying grades of sandpaper until the ring boundaries were clear when viewed under a microscope.

Rings were crossdated either by skeleton plotting (Stokes and Smiley 1968), or by preliminary measurement followed by computer checking of cross-correlation structure of measurements (Holmes 1983). Regardless of the method of initial crossdating, computer analysis was eventually used as a check on quality of dating and measurement (Holmes 1983). Measurements of ring-width were made to an accuracy of 0.01 mm with a Henson measuring machine (Pilcher 1990), and were stored in the standard ring-width format of the International Tree-Ring Data Bank (Grissino-Mayer et al. 1992).

Standarization

Standardization comprises a series of steps by which a set of measured ring-width series from individual trees is converted into a single time-series index of tree-growth suitable for studying large-scale environmental variations at a site (Figure 1). The first step in Standarization was to select the cores to be included in the chronology. We based this selection on the time coverage and quality of the individual ring-width series. Series from old trees were preferred over those from young trees. When a reasonably large number of samples from trees of varying age were available, cores from very young trees were sometimes excluded from the chronology. One reason for this screening is to avoid

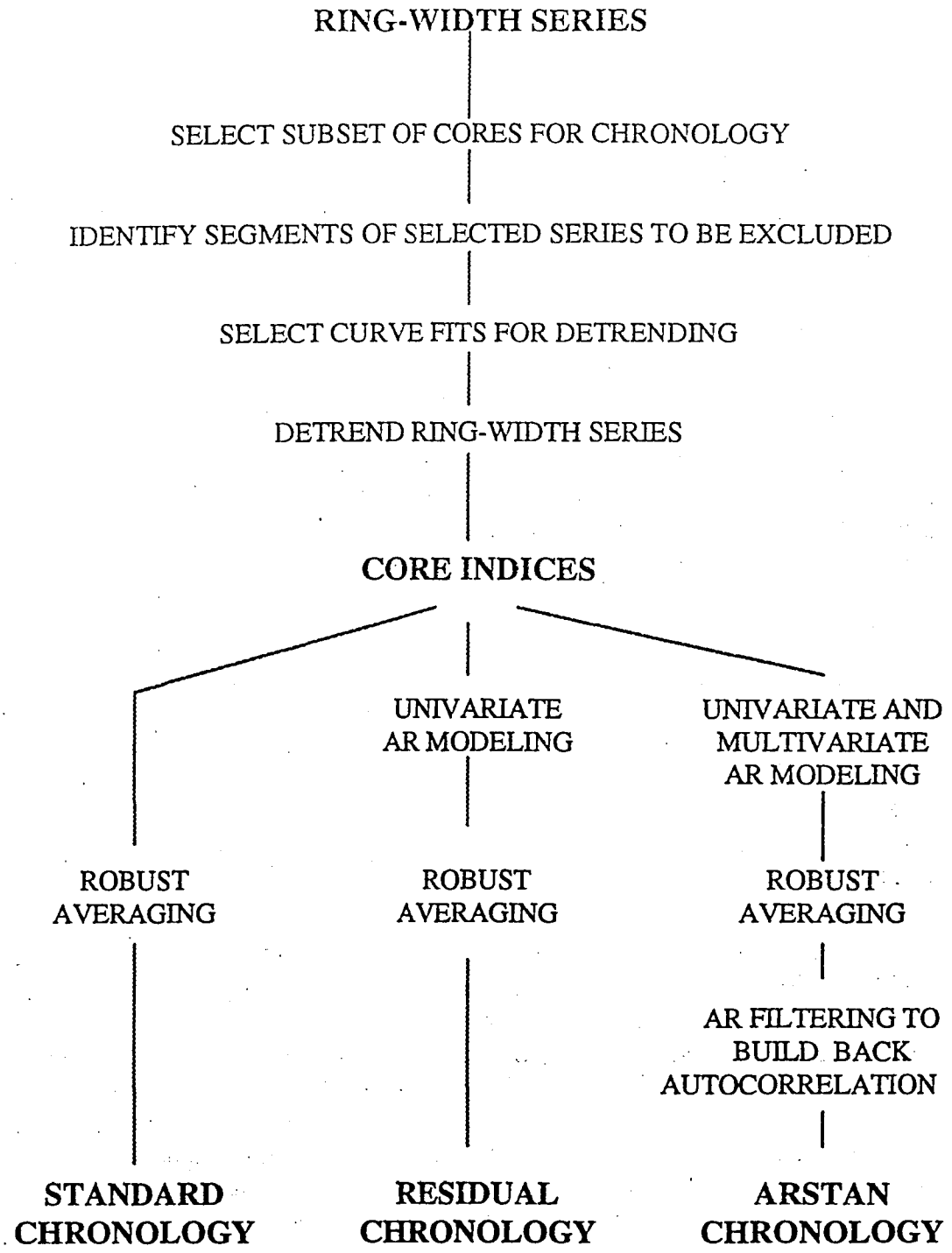


Figure 1. Steps for conversion of ring-width series to chronologies.

unnecessarily large changes in sample size (number of cores) in the mean-value series of the final chronology. Another reason is avoid the possible damping of low-frequency variance in the most recent part of the final chronology. The damping results from averaging of variable-length time series that have been individually detrended to remove variance at wavelengths longer than a specified fraction of the sample length.

The quality of ring-width series was judged by visual examination of the wood samples and time-series plots of ring width, evaluation of technicians' notes on crossdating or measurement problems, and consideration of cross-correlation statistics from program COFECHA (Holmes 1983). COFECHA computes sliding cross-correlations between segments of high-pass-filtered ring-width series. Each core's series is correlated with a "master" series that is the average of all the other filtered series. Cores whose filtered ring widths correlated unusually low with the master were often deleted from further consideration in building the chronology. The COFECHA results were also used to flag for deletion segments of ring-width series for which correlation with the master was anomalously low. Time series plots were examined along with the wood samples to identify periods of juvenile growth and periods of surges or suppressions in growth likely to be caused by injury or disease. The corresponding ring-width segments were generally omitted from the chronology.

The second step in standardization was to detrend the ring-width series. Detrending is necessary because ring width generally has an underlying trend not related to climate. Rings usually become narrower toward the outside of the tree because the annual increment of new wood is distributed over a larger and larger circumference. Moreover, annual wood production probably changes over the life span of the tree due to biological changes associated with aging. The most conservative detrending is to remove any monotonic trend over the full length of the series. More severe detrending might be required if low-frequency ring-width variations other than monotonic trends are asynchronous among the cores.

Ring-width series were detrended using program ARSTAN (Cook and Holmes 1984; Grissino-Mayer et al. 1992). We used the "double detrending" option, which allows for sequential removal of trend in two stages. A trend line is first fit to a ring-width series, and the ring-width value in each year is divided by the corresponding value of the trend line to get an initial core index. A second trend line is then fit to the initial core index, and the values of the initial core index are divided by the corresponding values of the second trend line to get the final core index. Our substantive application of double detrending was for ring-width series with a negative-exponential form of decay. In other cases, as described below, the second detrending was essentially a null operation.

The most subjective part of standardization is the choice of the mathematical form of the curve fits. We based this choice on visual examination of the ring-width plots. Series in this report are covered by the following choices:

1. Modified negative exponential curve, followed by cubic smoothing spline with an amplitude of frequency response of 0.5 at a specified wavelength. The negative exponential as a detrending function in dendrochronology is described by Fritts (1976); the spline is described by Cook and Peters (1981). The negative exponential was specified

as the first curve fit if ring-width series sharply declined from a period of wide rings associated with youth, then more gradually declined in later years. The second detrending (spline) in this case circumvents a shortcoming of modified negative exponential that can lead to artificial trends in the most recent years of core indices (Holmes et al. 1986). The stiffness of the spline can be controlled by varying a single parameter: at one extreme of the parameter's value, the spline is equivalent to a least-square-fit straight line, and at the other extreme the spline passes through all points in the original time series.

2. Cubic smoothing spline with an amplitude of frequency response of 0.5 at a specified wavelength, followed by a horizontal line through the mean. The spline was specified as the first curve fit if the ring width changed gradually over the length of the series, but lacked a sharp initial decline characteristic of the negative exponential. We detrended conservatively to reduce the risk of removing low-frequency climate information from the ring widths. Accordingly, a spline with an amplitude of frequency response of 0.5 at 67-100% of the series length or longer was specified (Cook et al., 1990a). The second curve fit -- the horizontal line through the mean -- is essentially a null operation that does not remove additional trend from the series..

3. Least-squares-fit straight line of negative or zero slope, followed by horizontal line though the mean. This option was used with some relatively short ring-width series with synchronous low-frequency variations also present in longer ring-width series. Application of option 2 in this case could obscure important low-frequency climate information. For example, assume the data set consists of several 100-year ring-width series dominated by a synchronous low-frequency component resembling a sine wave with a period of 67 years in the 20th century, and one or more longer series also containing the 67-year fluctuation. The presence of the fluctuation in the longer series indicates a possible climatic rather than age-trend source of the fluctuation. But use of option 2 with, say, a spline with 0.5 frequency response at 2/3 the series length would severely damp the fluctuation in the short series, and consequently in the mean-value series of the site chronology.

Each core-index series derived by the procedure just described could be used by itself as a variable to reconstruct the climate variable of interest. The individual core indices are likely to contain a "noisy" climate signal, however, due to tree-specific distortions in ring width from microenvironmental factors, such as disease, injury, or changes in competition for light and moisture.

The third step in standardization was to attempt to reduce such localized distortions by averaging core indices across the site. The average series is called the "standard chronology". ARSTAN computes a biweight mean rather than a straight arithmetic mean to discount the influence of outliers (Mosteller and Tukey 1977; Cook et al, 1990b).

In addition the standard chronology, ARSTAN optionally produces two other versions of the chronology from the core indices -- a "residual chronology" and an "ARSTAN chronology". The residual chronology is formed by averaging residuals of autoregressive (AR) models fit to the individual core indices. The residual chronology differs from the standard chronology in that autocorrelation is removed from the core

indices before averaging into a site chronology. Why remove autocorrelation? First, ring-width series even after detrending are sometimes much more highly autocorrelated than the annual time series of climate variables thought to be governing the variations in growth (Cook et al. 1990b) . Second, the biological system of the tree has several possible pathways for carryover of growth anomalies from one year to the next (Fritts 1976). Prewhitening by AR modeling is therefore aimed at removing "undesirable autocorrelation from tree-ring series. Prewhitening often improves the correlation between tree-ring and climate variables (Meko 1981). It is unreasonable, however, to expect the AR filter to remove autocorrelation optimally in preparing the tree-ring series as a predictor variable for reconstructing climate.

The "ARSTAN" version of the site chronology also is derived by AR modeling, but retains the common autocorrelation structure in the core indices. In deriving the ARSTAN chronology, each core index is modeled as an AR process. The order of the AR model is the same for all cores, and is determined by multivariate AR modeling (Cook 1985). As with the residual chronology, the biweight mean of the AR residuals is then computed -- with the effect of emphasizing the common signal and discounting outliers. Autocorrelation is then built back into the mean residual series by filtering it with the global AR model determined previously by the multivariate AR modeling. In practice, the standard chronology usually differs little from the ARSTAN chronology. The plots and analysis on the snapshot pages in this report use only the standard chronology. The standard and residual chronologies are included in the computer files on diskette.

Modeling the Tree-Ring Response to Annual Precipitation

Linear dynamic modeling, as described by Ljung (1987), was used to evaluate the annual precipitation signal in the individual chronologies. We assume at the outset a climate variable of interest -- precipitation totaled over the months September through August. Earlier studies have indicated that tree-ring series from the Dakotas effectively integrate precipitation over several seasons, and that the September-August grouping is reasonable for capturing the response (Meko 1982; Stockton and Meko 1983; Ni 1993).

Because tree-growth in the current year is affected by current and past years' climate, the climate-tree ring relationship is inherently dynamic. Although many biological pathways in the climate-tree ring system are nonlinear (Fritts 1976), and some tree-ring studies have demonstrated nonlinearity in the relationship between tree-ring indices and climate variables (e.g., Graumlich 1991), regression studies have generally indicated that linearity is a reasonable assumption in the net tree-ring response to precipitation and other drought variables (e.g., Stockton and Meko 1983; Cleaveland and Stahle 1989; Cleaveland and Duvick 1992). Linear dynamic modeling is therefore a reasonable approach for studying the relationship between annual precipitation and the tree-ring index.

The models to be used are simplifications of the general linear transfer function model described by (Ljung 1987) relating a time series input to a time series output. In our application, the output is a tree-ring variable and the input is a climate variable. Assume a linear system with input $u(t)$ and output $y(t)$ such that the output can be expressed as a weighted function of past and current values of the input plus noise:

$$y_t = G(q)u(t) + v(t), \tag{1}$$

where $v(t)$ is the noise and $G(q)$ is the transfer function

$$G(q) = \sum_{k=0}^{\infty} g(k)q^{-k}, \tag{2}$$

with impulse response weights $g(k)$, $k=0,1,...$; and shift operator q^{-k} defined by

$$q^{-k}u(t) = u(t-k) \tag{3}$$

The noise is assumed to be generated from white noise $e(t)$ by a function $H(q)$:

$$v(t) = H(q)e(t) \tag{4}$$

where $H(q)$ has the same form as $G(q)$ in (2). Substituting (4) into (1), we obtain

$$y_t = G(q)u(t) + H(q)e(t), \tag{5}$$

which expresses the output as a weighted function of past and current input and filtered white noise. The model given by (5) is flexible in that the noise component is allowed to have its own autocorrelation structure, and that past as well as current values of the input are allowed to affect the output.

As shown by Ljung(1987), equation (5) can be parameterized in terms of rational functions to obtain:

$$A(q)y(t) = \frac{B(q)}{F(q)}u(t-nk) + \frac{C(q)}{D(q)}e(t), \tag{6}$$

where A, B, C, D, and F are polynomials of order na, nb, nc, nd, nf in the shift operator q^{-k}, and nk is the delay between input and its initial effect on output. The polynomial B is

$$B(q) = b_1 + b_2q^{-1} + ... + b_{nb}q^{-nb+1}, \tag{7}$$

and the polynomials A, C, D, and F are

$$A(q) = 1 + a_1 q^{-1} + \ldots + a_{na} q^{-na}, \qquad (8)$$

$$C(q) = 1 + c_1 q^{-1} + \ldots + c_{nc} q^{-nc},$$

$$D(q) = 1 + d_1 q^{-1} + \ldots + d_{nd} q^{-nd},$$

$$F(q) = 1 + f_1 q^{-1} + \ldots + f_{nf} q^{-nf},$$

where $a_1,\ldots,a_{na}$; $b_1,\ldots,b_{nb}$, and so forth, are model parameters to be estimated.

The two model structures used in this report are the output-error (OE) model and the autoregressive "extra" (ARX) model. These model are simplifications of the general model described by (6). The OE and ARX models have not been previously applied in dendroclimatology, but are similar in form to the Box-Jenkins transfer function models explored as a diagnostic tool in dendroclimatology by Meko (1981).

The model structures can be described in terms of filtering of the input climate variable *u(t)* and white noise *e(t)* by polynomials in the shift operator *q* to produce an output tree-ring variable *y(t)* (Figure 2). The OE model generates *y(t)* by adding white noise added to the filtered climate variable. The ARX model generates *y(t)* by adding *filtered* white noise to the filtered climate variable (Figure 2). The models are described briefly below using the notation of Ljung (1987).

Output-Error Structure

The *OE(nb,nf)* structure is

$$y_t = \frac{B}{F} u(t) + e(t), \qquad (9)$$

where B and F are polynomials of order *nb* and *nf* in the shift operator, as described above. Because the ratio *B/F* also is a polynomial in the shift operator, the OE model effectively expresses the tree-ring series as a weighted average of past and current climate with superposed white noise (Figure 2). In the trivial case of *nb=1* and *nf=0*, the model indicates a contemporaneous response of tree rings to climate -- no lag in response. If *nf=0* and *nb>1*, the model gives the tree-ring index as white noise superimposed on a weighted average of *nb* years of climate. Adding a denominator term (*nf>0*) allows for parsimonious expression of more complicated weighting of importance of several years of climate -- for example, *nb*=1 and *nf*=1 allows for geometrically decreasing importance of climate with lag from year *t*.

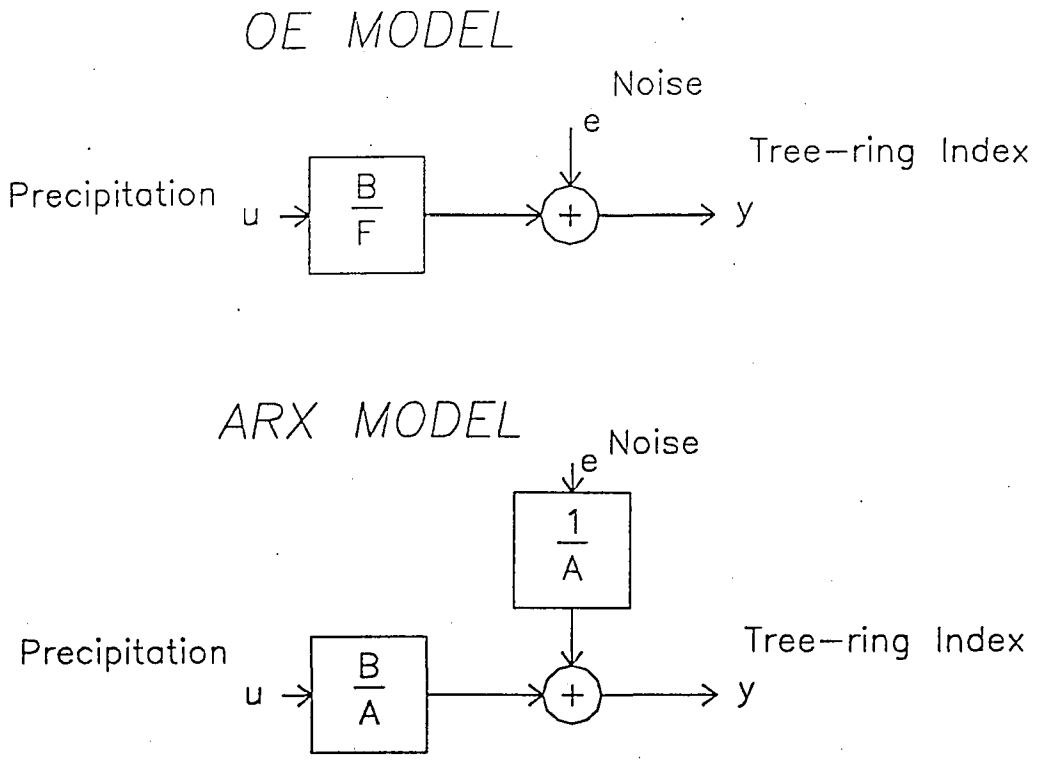


Figure 2. Diagram illustrating the relationships among input, output and noise for the output-error (OE) and autoregressive-"extra" (ARX) model structures. Terms in the boxes are polynomial operators. The input, output and noise are time series. The "+" inside the circle indicates that the model is additive. The model structures are described in more detail in the text.

ARX Structure

The ARX *(na,nb)* structure is given

$$Ay(t) = Bu(t) + e(t), \tag{10}$$

or

$$y(t) = \frac{B}{A}u(t) + \frac{1}{A}e(t), \tag{11}$$

where the operators A and B are functions of the shift operator with orders *na* and *nb* as defined in (17 and (18).

The structure is called "ARX" because it contains an autoregressive part and an "extra" input consisting of the filtered *u(t)* (Ljung 1987). Equations (10) and (11) are alternative formulations of the same system. In (10), the filtered tree-ring index is viewed as the sum of a filtered climate series and white noise. In (11), the tree-ring index (not filtered) is viewed as the sum of filtered climate and filtered white noise. The model is slightly restrictive in that the noise model and the transfer function model are not parameterized independently. The input and the noise are assumed to pass through the same denominator filter *A(q)* before being added together to form the output (Figure 2).

Modeling Steps

The precipitation-tree ring relationship was modeled separately for individual chronologies, using as output the standard chronology, and as input the annual (September-August) precipitation averaged over nearby climate stations.

The steps in modeling were as follows: (1) select the maximum orders of ARX and OE models to be considered, (2) fit the candidate models to the data, (3) examine goodness-of-fit statistics and properties of residuals to identify the structure and orders of the model most appropriate to the data, and (4) apply the best-fit ARX and OE models to generate one-step ahead predictions of the chronology for the period in common to the precipitation and tree-ring series.

The set of OE models considered had orders *nb* ranging from 1 to 3 and *nf* ranging from 1 to 2. The set of ARX models considered had orders *na* ranging from 1 to 3 and *nb* ranging from 1 to 3. The delay parameter *nk* was set to nk=0 years because the first impact of anomalous August-September precipitation in the year ending in September of year *t* logically falls on the ring for year *t*. Models were fit with all possible combinations of model orders within the ranges listed above.

Model parameters for the OE structure were estimated by an iterative Guass-Newton algorithm (Ljung 1987, p.283). Parameters for the ARX structure were estimated by least squares. The "best" model among and within model structures was selected using Akaike's Final Prediction Error (FPE) criterion (Ljung 1987, p. 152):

$$\mathrm{FPE} = \frac{1+n/N}{1-n/N} * V, \qquad (12)$$

where n is the total number of parameters, N is the total number of years of data in the calibration period, and V is a quadratic loss function proportional to the averaged squared residual error (Ljung 1987, p. 420). The autocorrelation function of the residuals and scatterplots of the residuals against the input were examined as a check on goodness-of-fit

The best-fit OE and ARX models were used to generate one-step-ahead predictions of the tree-ring index from the fitted models. Visual comparison of these predictions with the observed output (tree-ring) series gives insight into model performance. "One-step-ahead" refers to the use of predictor values up to and including year *t-1* in the prediction for the tree-ring index in year *t*. Because the ARX model includes past values of the output as predictors, high accuracy of ARX prediction could result from persistence alone. The OE model, on the other hand, does not include past values of the output (tree-series) as predictors, and so will not automatically give accurate one-step-ahead predictions just because the tree-ring index is highly autocorrelated. Accurate prediction with the OE model depends on a statistical relationship between the current year's tree-ring value and the sequence of past and current years' climate.

The accuracy of the one-step-ahead predictions of the tree-ring chronology using the OE and ARX models was measured by a reduction-of-variance statistic similar to regression R^2:

$$\mathrm{RV} = 1 - \frac{V_e}{V_y} \qquad (13)$$

where V_e is the estimated variance of the residuals of the model (observed minus predicted tree-ring series) and V_y is the variance of the observed tree-ring series..

Tree-Ring Collections

Old trees were located by a variety of methods. Early publications identifed potential study sites. Local land owners and public agency personnel often verified locations and suggested additional sites. Most trees were located through extensive ground reconnaissance. In many cases, areas least accessible to humans and wildfires provided the best specimens. Dry, upland sites such as ridges and steep hillsides often supported old trees.

A "site" for purposes of this report is defined as a collection of one or more core samples from the same general location. A total of 53 sites were collected in this study. The site locations are shown on the map in Figure 3, and basic information on the collections is listed in Table 1. The core samples from a site were labeled with a three-letter code unique within this project; the code is listed in column 3. The number of trees sampled at a site varied from 1 to 25. Some sites were reconnaissance collections to check out leads on reportedly old trees; one tree was often a sufficient sample to determine that the age had been overestimated and that the site was not worthy of further collection. Sample size is smaller than desirable (10 trees) at many sites simply because of a shortage of trees. Samples were from living trees, except for those from Fort Sisseton (site #49), which were from the beams of a fort built in the late 1800s.

Sites cluster densely around the Black Hills in southwestern South Dakota. All except two of the sites are in North Dakota or South Dakota. The exceptions are Middle Hay Fork, at the western edge of the Black Hills in far eastern Wyoming; and Stone State Park, in the northeastern corner of Iowa. Elevations at the sites range from 1783 m for Upper Pine Creek Recreation Area (site #38), in the Black Hills of South Dakota, to less than 300 m for Pembina Hills and Icelandic State Park (sites #51, 52), in the northeastern corner of North Dakota.

Most sites are represented in the collections by one of three species -- bur oak (*Quercus macrocarpa*), ponderosa pine (*Pinus ponderosa*), or Rocky Mountain juniper (*Juniperus scopulorum*). Two species were collected at three of the sites: ponderosa pine and juniper at Cedar Butte (site #42), and bur oak and ponderosa pine at Frawley (site #13) and Grace Coolidge Creek East (site #17). Bur oak sites are most numerous in the collection, mainly because bur oak is the most widely distributed dendroclimatological tree species across the vast expanses of the prairies of North and South Dakota (Little 1971).

The field collections began on June 7, 1991, with Crowley (site #1), and ended on October 28, 1992, with Mt. Rushmore (site #41). As indicated by the next to last column in Table 1, the sites were at various stages of processing at the time this report was written. For most of the sites collected in 1991, crossdating and measurement have been completed, and the data -- if of high quality -- have been incorporated into a site chronology. Because of time constraints, data from some sites with good potential collected in 1992 have not yet been developed into chronologies.

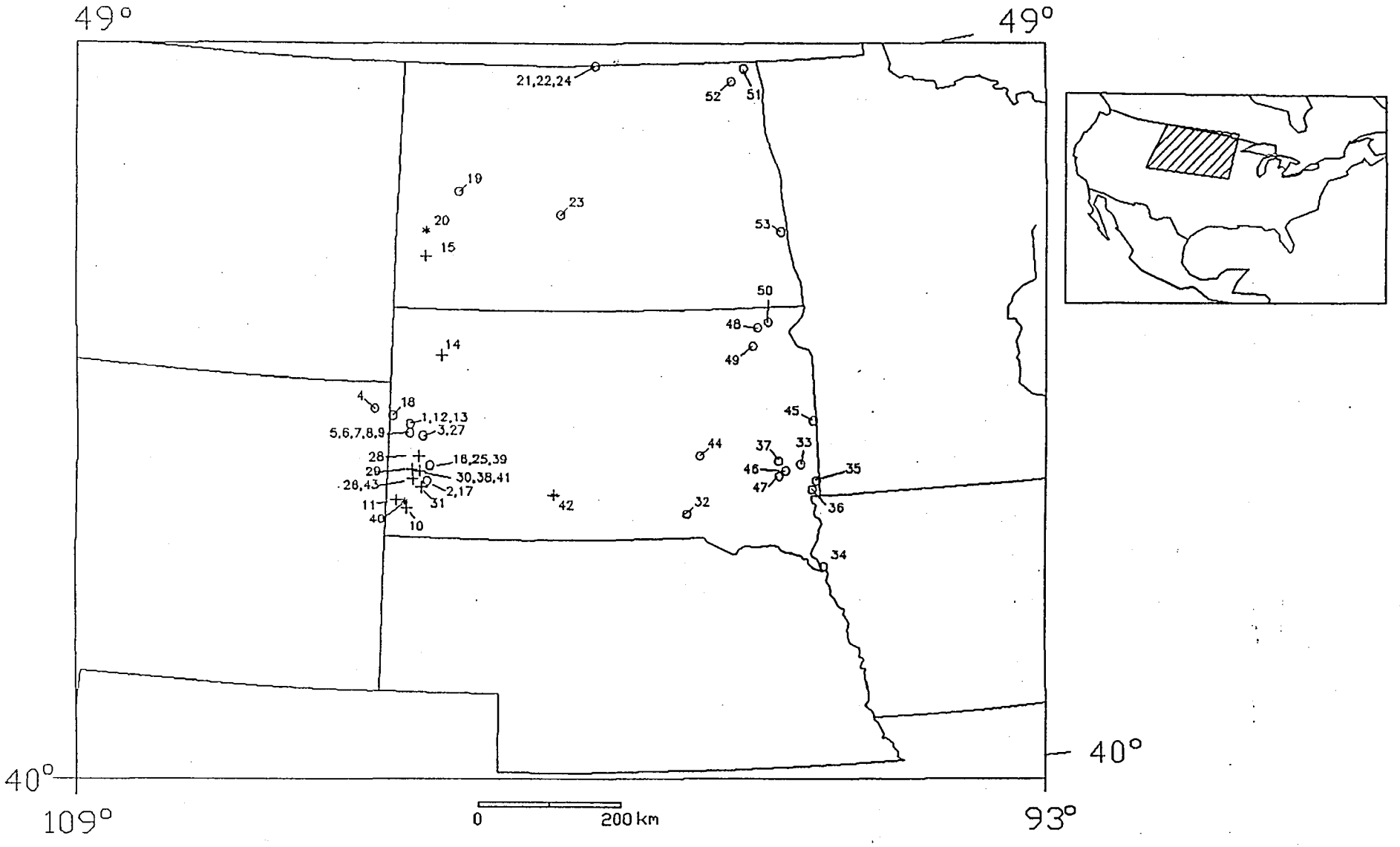


Figure 3. Map showing locations of tree-ring collections. Numbers are cross-referenced to site information in Table 1. Species are coded by symbols: "o" for *Quercus macrocarpa*, "+" for *Pinus ponderosa*, and "*" for *Juniperus scopulorum*.

Table 1. Summary information on tree-ring sites.

MAP NO.	SITE NAME	SITE CODE	STATE	LAT.	LONG.	EL(m)	N_t	SPECIES	COLLECTOR	DATE COLL.	S	FIRST YEAR
1	CROWLEY	CRW	SD	44 35	103 43	1033	1	QUMA	S1 D1	06/07/91	R	1933
2	CUSTER STATE PARK	CSP	SD	43 45	103 23	1340	6	QUMA	D1	06/11/91	C	1775
3	SNYDER	SNY	SD	44 18	103 26	1137	2	QUMA	D1	06/12/91	C	1877
4	MIDDLE FORK HAY CREEK	MFH	WY	44 40	104 19	1280	8	QUMA	D1 M2	06/12/91	R	1790
5	HANKINS	HNK	SD	44 20	103 41	1520	2	QUMA	D1 H1	06/13/91	C	1735
6	ORDAHL	ORD	SD	44 22	103 41	1510	1	QUMA	D1 H1	06/13/91	M	1883
7	OAK RIDGE CEMETERY	ORC	SD	44 23	103 40	1420	4	QUMA	D1 H1	06/13/91	C	1878
8	HARVEY	HRV	SD	44 23	103 40	1390	1	QUMA	D1 H1	06/13/91	M	1892
9	WILSON	WIL	SD	44 26	103 37	1189	3	QUMA	D1	06/14/91	C	1733
10	PARKER PEAK LOOKOUT	PPK	SD	43 23	103 41	1478	10	PIPO	M1 S1 D1	06/18/91	M	1654
11	PILGER MOUNTAIN	PLG	SD	43 30	103 53	1392	3	PIPO	M1 S1 D1	06/18/91	C	1710
12	FRAWLEY DAIRY FARM	FDF	SD	44 28	103 40	1130	6	QUMA	M1 S1 D1	06/19/91	C	1807
13	FRAWLEY	FRW	SD	44 29	103 41	1230	13	QUMA PIPO	M1 S1 D1	06/19/91	C	1858
14	EAGLE NEST CANYON	ENC	SD	45 21	103 8	1090	21	PIPO	M1 S1 D1 D3	06/21/91	C	1651
15	BURNING COAL VEIN	BCV	ND	46 36	103 28	792	20	PIPO	M1 D1	06/22/91	C	1592
16	CRYSTAL CAVE	CRY	SD	43 57	103 18	1230	12	QUMA	D1 J1	07/02/91	C	1833
17	GRACE COOLIDE CREEK EAST	GCE	SD	43 45	103 21	1234	30	QUMA PIPO	D1	07/10/91	C	1703
18	THOMPSON RANCH	THO	SD	44 35	104 0	1036	5	QUMA	D1	07/17/91	C	1747
19	KILLDEER - DVIRNAK	KDD	ND	47 25	102 55	823	25	QUMA	D1 F1	09/18/91	C	1777
20	THEODORE ROOSEVELT NTL PK	TRS	ND	46 55	103 29	747	22	JUSC	D1 F1	09/25/91	C	1466
21	BEAR ISLAND	BRI	ND	48 59	100 21	660	11	QUMA	F1 D1	10/08/91	C	1782
22	MASONIC ISLAND	MAI	ND	48 59	100 20	657	2	QUMA	F1 D1	10/08/91	C	1834
23	CROSS RANCH - SANGER UNIT	CRS	ND	47 9	101 1	442	16	QUMA	F1 D1	10/09/91	C	1788
24	LAKE METIGOSHE STATE PARK	MET	ND	48 58	100 18	672	1	QUMA	F1 D1	10/09/91	C	1676
25	ROCKERVILLE	ROC	SD	43 56	103 22	1370	6	QUMA	D1 D2	02/20/92	C	1717
26	BUCKHORN MOUNTAIN	BHM	SD	43 47	103 36	1768	18	PIPO	D1 F1	04/05/92	C	1600
27	BLAIR RANCH	BLR	SD	44 20	103 26	1097	9	QUMA	D1 D2	04/06/92	C	1751
28	VETERAN'S POINT	VET	SD	44 5	103 30	1402	1	PIPO	D1 T1	04/08/92	R	1778
29	RENO GULCH	REN	SD	43 54	103 36	1658	17	PIPO	S1 D1 J1	04/09/92	C	1281

Table 1. Summary infomation on tree-ring sites (continued).

MAP NO.	SITE NAME	SITE CODE	STATE	LAT.	LONG.	EL(m)	N_t	SPECIES	COLLECTOR	DATE COLL.	S	FIRST YEAR
30	HORSE THIEF LAKE	HTL	SD	43 53	103 28	1520	2	PIPO	D1 F1	04/10/92	M	1616
31	BIG TREE DRAW	BTD	SD	43 41	103 26	1390	2	PIPO	D1 F1	04/10/92	C	1646
32	PLATTE CREEK	PLC	SD	43 19	98 49	440	1	QUMA	D1 D2	05/18/92	R	1895
33	UNION STATE PARK	USP	SD	43 55	96 46	410	5	QUMA	D1 D2	05/19/92	R	1876
34	STONE STATE PARK	SSP	IA	42 33	96 28	396	13	QUMA	D1 D2	05/20/92	C	1796
35	PALISADES STATE PARK	PSP	SD	43 41	96 31	450	2	QUMA	D1 B1	05/26/92	R	1898
36	BIG SIOUX RECREATION AREA	BSR	SD	43 35	96 35	402	16	QUMA	D1 B1	05/27/92	R	1850
37	LAKE HERMAN STATE PARK	HRM	SD	43 59	97 10	512	7	QUMA	D1 B1	05/29/92	C	1740
38	UPPER PINE CREEK NAT AREA	UPC	SD	43 52	103 31	1783	8	PIPO	D1	06/03/92	M	1543
39	SPRING CREEK CAMPGROUND	SPR	SD	43 59	103 25	1344	2	QUMA	D1 D2	09/30/92	R	1796
40	WALLY ADRIAN	ADR	SD	43 29	103 43	1250	3	JUSC	D1 F1	09/29/92	R	1763
41	MT. RUSHMORE	RUS	SD	43 52	103 27	1737	12	PIPO	D1	10/28/92	M	1614
42	CEDAR BUTTE	CED	SD	43 36	101 7	785	17	PIPO JUSC	B1 D1	06/25/92	C	1646
43	CUSTER	CST	SD	43 47	103 36	1695	10	PIPO	M1 D1	06/17/91	R	1754
44	WESSINGTON SPRINGS CITY PARK	WES	SD	44 5	98 34	380	5	QUMA	D1 B1	06/18/92	M	1753
45	GILLY'S GROVE	GIL	SD	44 28	96 31	550	21	QUMA	D1 B1	10/06/92	M	1882
46	ORLAND HUTTERITE COLONY	ORL	SD	43 51	97 3	523	10	QUMA	D1 B1	06/08/92	C	1883
47	JENNINGS FARM	JEN	SD	43 47	97 10	490	1	QUMA	D1 B1	06/09/92	M	1913
48	ROY LAKE	ROY	SD	45 41	97 26	520	2	QUMA	D1 B1	06/16/92	M	1916
49	FORT SISSETON	SIS	SD	45 27	97 32	540	2	QUMA	D1 B1	06/16/92	M	1696
50	SICA (SIECHE) HOLLOW	SIC	SD	45 45	97 14	550	3	QUMA	D1 B1	06/16/92	M	1891
51	PEMBINA HILLS	PEM	ND	48 55	97 30	240	10	QUMA	G1 D1	09/22/92	C	1831
52	ICELANDIC STATE PARK	ICE	ND	48 46	97 45	297	5	QUMA	G1 D1	09/22/92	C	1830
53	FARGO	FAR	ND	46 53	96 55	274	2	QUMA	G1 D1	09/24/92	M	1874

Key to Table 1.

MAP NO. -- site number on map in Figure 1.

SITE NAME -- name of site; originially assigned in field notes

SITE CODE -- three-letter code used to label wood samples; derived from site name

STATE -- South Dakota (SD), North Datota (ND), Iowa (IA), or Wyoming (WY)

LAT, LONG -- degrees and minutes of latitude and longitude

EL(m) -- approximate elevation in meters of site above mean sea level

N_t --number of trees sampled

SPECIES: tree species core-sampled:

QUMA -- *Quercus macrocarpa* (bur oak)
PIPO -- *Pinus ponderosa* (ponderosa pine)
JUSC -- *Juniperus scopulorum* (Rocky Mountain juniper)

(Occasional cores were sometimes taken from other species, but not with the intent of chronology development.)

COLLECTOR -- individual(s) doing the field sampling:

B1 - Jeff Baumberger
D1 - Shelly Deisch
D2 - Steve Denison
D3 - Arthur DeGaetano
F1 - Helen Fitting
G1 - Scott Gamo
H1 - R. Homann
J1 - Jody Javersak
M1 - David Meko
S1 - Carolyn Sieg

DATE -- date on which most of the cores were collected

STATUS -- status of the data processing

R - ring-count: estimated first year (see below) by ring-count only; crossdating incomplete
M - measured: at least some cores crossdated and measured, but measured series not used in a chronology in this report
C - chronology: samples crossdated, measured, and used in a chronology

First: approximate first measurable ring on any core; estimated for some sites

The earliest date of any core at each site is listed in the last column of Table 1. The oldest oak we found, from Lake Metigoshe State Park, near the Canadian border in north-central North Dakota, has 327 rings and an inner date of 1676. Our search indicates that bur oak trees with more than about 250 rings are rare in the Dakotas. None of the bur oak samples approach the 373-year length of the "master oak" stump near Bismark described by Will (1946).

The oldest of the Rocky Mountain juniper samples (Theodore Roosevelt National Park, site #20) had an inner ring at 1466. An exhaustive search of the Badlands would likely yield more old juniper samples. Considering just the Black Hills, ponderosa pine is clearly the best species for combined length and site replication. The oldest pine sample (Reno Gulch, site #29) begins in 1281, which is considerably earlier than any previous tree-ring sample from the Dakotas. Several of our reconnaissance pine collections from the Black Hills show that excellent potential exists for a long and well replicated tree-ring network. Limited sampling at Upper Pine Creek Natural Area (#38), Horse Thief Lake (#30), Mt. Rushmore, for example, yielded samples extending to the 1600s or earlier.

Chronologies

The collections described in the previous section yielded many more tree-ring samples than could be dated, measured and worked up into chronologies under the time and budgetary constraints of the project. Priority for development of chronologies was guided by the following considerations: (1) previous tree-ring data coverage in the region, (2) length of the tree-ring data, and (3) quality of the tree-ring data. First priority was given to extending the tree-ring spatial coverage into the sparsely sampled central and eastern parts of the Dakotas. Long tree-ring chronologies were of course preferred over short chronologies whose early years do not precede or barely precede the establishment of climatological stations. Other factors being equal, sites whose detrended ring-width series were highly intercorrelated and relatively free from other statistical problems (see Methods) were preferred for chronology development

A total of 27 tree-ring chronologies have been developed so far. Information on the chronologies is listed in Table 2, and locations of sites or groups of sites from which the samples making up the chronology were drawn are shown on the map in Figure 3. Each chronology is uniquely identified within this study by the 3-letter code in column 3 of Table 2. The chronologies are cross-referenced to the 53 tree-ring sites by the 3-letter site codes in column 4. For example, chronology HNK is made up of cores from sites HNK, WIL and ORC. Some sites yielded multiple chronologies (e.g., juniper and pine chronologies CEJ and CED from the Cedar Butte (CED) site.

Each chronology is made up of a single species. Eighteen are bur oak, 7 are ponderosa pine, and 2 are Rocky Mountain juniper. Because questionable ring-width series were deleted or truncated in chronology development, the beginning year of the chronology as listed in Table 2 is sometimes later than the first year of the earliest dated ring at the site(s) as listed in Table 1. For example, the earliest ring in the Theodore Roosevelt collection is 1466, but because of uncertain crossdating the TRS chronology begins in 1630.

Summary Statistics

The last 8 columns in Table 2 (columns 9-16) contain statistical information for a "common interval" for which a subset of cores has complete data. The years for the common interval are listed in columns 9-10, and the number of trees and cores in the common-interval data set are listed in columns 11-12. Column 13 lists the first-order autocorrelation coefficient of the standard chronology. All of the chronologies are positively autocorrelated, and even the lowest of the autocorrelation coefficients (0.25, for chronology FRO) is significantly different from zero at the 95 percent confidence level (Panofsky and Brier 1968).

The last three columns in Table 2 contain statistics for evaluating the internal consistency of the chronology, and in particular for determining whether the sample size is adequate for estimating the population tree-ring variations at the site. The mean between-tree correlation coefficient is listed in column 14. This statistic is the mean of the

Table 2. Summary statistics on chronologies. (See key on next page.)

NO.	NAME	CHRON. CODE	SITES	MAP NO.	SPECIES	CHRONOLOGY YEARS		COMMON INTERVAL ANALYSIS YEARS		$N_t(N)_c$	r(1)	r_{bt}	EPS	$N_{.85}$
1	Custer State Park	CSP	CSP	2	QUMA	1775	1990	1796	1989	4 (4)	0.74	0.42	0.75	3
2	Thompson	THO	THO	18	QUMA	1747	1990	1913	1990	4 (5)	0.31	0.56	0.83	3
3	Frawley Dairy Farm	FDF	FDF	12	QUMA	1807	1990	1896	1990	6 (9)	0.48	0.51	0.86	3
4	Crystal Cave	CRY	CRY	16	QUMA	1833	1990	1906	1990	7 (8)	0.29	0.45	0.85	4
5	Frawley Oak	FRO	FRO	13	QUMA	1892	1990	1914	1990	3 (7)	0.25	0.57	0.80	2
6	Eagle Nest Canyon	ENC	END	14	PIPO	1651	1990	1864	1990	16 (26)	0.59	0.51	0.94	4
7	Grace Coolidge Oak	GCE	GCE	17	QUMA	1767	1991	1891	1990	9 (14)	0.53	0.47	0.89	4
8	Grace Coolidge Pine	GCP	GCE	17	PIPO	1703	1990	1841	1986	6 (11)	0.55	0.50	0.86	3
9	Hankins Group	HNK	HNK WIL ORC	5	QUMA	1875	1990	1901	1990	5 (6)	0.46	0.35	0.73	4
10	Blair	BLR	BLR	27	QUMA	1753	1990	1880	1990	5 (8)	0.44	0.50	0.83	3
11	Burning Coal Vein	BCV	BCV	15	PIPO	1592	1990	1807	1983	18 (35)	0.57	0.53	0.95	4
12	Pilger Mountain	PLG	PLG BTD	11	PIPO	1646	1991	1833	1971	5 (8)	0.54	0.53	0.85	3
13	Theodore Roosevelt National Park	TRS	TRS	20	JUSC	1630	1991	1897	1990	12 (18)	0.56	0.51	0.92	4
14	Killdeer-Dvirnak	KDD	KDD	19	QUMA	1777	1990	1911	1990	15 (21)	0.42	0.47	0.93	5
15	Cross Ranch -- Sanger Unit	CRS	CRS	23	QUMA	1788	1990	1909	1990	8 (11)	0.55	0.41	0.85	4
16	Bear Island	BRI	BRI	21	QUMA	1801	1990	1862	1988	3 (5)	0.54	0.46	0.72	2
17	Masonic Island	MAI	MAI MET	22	QUMA	1676	1990	1861	1990	3 (6)	0.62	0.47	0.72	2
18	Rockerville	ROC	ROC	25	QUMA	1717	1990	1901	1990	5 (8)	0.55	0.33	0.71	4
19	Reno Gulch	REN	REN	29	PIPO	1281	1991	1794	1980	12 (17)	0.60	0.38	0.88	5
20	Stone State Park	SSP	SSP	34	QUMA	1796	1991	1900	1990	11 (20)	0.45	0.47	0.91	4
21	Buckhorn Mountain	BHM	BHM	26	PIPO	1600	1991	1788	1990	16 (25)	0.42	0.52	0.94	4
22	Cedar Butte Pine	CED	CED	42	PIPO	1646	1991	1845	1991	8 (13)	0.59	0.57	0.91	3
23	Cedar Butte Juniper	CEJ	CED	42	JUSC	1691	1991	1857	1973	5 (13)	0.53	0.50	0.86	3
24	Lake Herman State Park	HRM	HRM	37	QUMA	1740	1991	1896	1991	5 (8)	0.60	0.43	0.79	3
25	Orland Hutterite Colony	ORL	ORL	46	QUMA	1859	1991	1911	1991	11 (19)	0.41	0.59	0.93	3
26	Icelandic State Park	ICE	ICE	52	QUMA	1830	1992	1905	1991	5 (8)	0.39	0.40	0.77	3
27	Pembina Hills	PEM	PEM	51	QUMA	1831	1992	1901	1992	9 (15)	0.45	0.38	0.85	5

Key to Table 2.

NO. -- sequential number of chronology. Chronologies are presented in this order in individual text and graphical summaries.

NAME -- name of chronology. Identical to or derived from name of the main site contributing cores to the chronology. For example, the "Cedar Butte Pine" chronology (#22) is built from the ponderosa pine subset of cores from the "Cedar Butte" site (Table 1).

SITES -- three-letter code(s) of the site(s) contributing cores to the chronology. This code is cross-referenced to Table 1. If the chronology includes cores from multiple sites, the first code in the series refers to the main site.

MAP NO. -- number on map in Figure 1 marking the location of the main site for the chronology

SPECIES -- species of chronology (Each chronology is of a single species.):

QUMA -- *Quercus macrocarpa* (bur oak)
PIPO -- *Pinus ponderosa* (ponderosa pine)
JUSC -- *Juniperus scopulorum* (Rocky Mountain juniper)

CHRONOLOGY YEARS -- beginning and ending year of the standard chronology.

COMMON INTERVAL ANALYSIS

The statistics in this section are from the "Common Interval Analysis" section of output from program ARSTAN. The statistic **r(1)** is computed on the core indices; statistics **rbt, EPS, and $r_{0.85}$** are computed on the AR residuals of the core indices.

YEARS -- beginning and ending year of common interval.
$N_t(N_c)$ -- number of trees and number of cores included in the common interval analysis.
r(1) -- first-order autocorrelation coefficient of the core indices (detrended series, not AR residuals)
r_{bt} -- mean correlation coefficient for pairs of core indices from different trees (between-tree correlation)
EPS -- expressed population signal -- theoetical estimate of the percentage of variance of an infinite-sized (infinite number of trees) chronology contained in the "full" chronology of N_t trees
$r_{0.85}$ -- theoretical threshold number of trees required for the chronology to contain 85% of the variance of the full chronology -- which has N_t trees

correlation coefficients for pairs of core indices from different trees. A high between-tree correlation is desirable for dendroclimatological applications because climatic variation is a large-scale environmental influence on growth. The correlations in Table 2 range from 0.33 for ROC (#18) to 0.59 for ORL (#25). No obvious species dependence was found in the correlations.

Columns 15 and 16 list statistics developed by Wigley et al. (1984) for judging the suitability of the sample size for capturing the hypothetical "true" tree-ring variably at the site. Consider an N-tree chronology, computed by averaging the core indices from the N trees in the common interval, and a smaller n-tree chronology, computed by averaging the core indices from the variable-sized sample in any given year of the chronology. Also consider a hypothetical "infinite-tree" chronology, which would result from averaging core indices from an infinite number of trees at the site. The expressed population signal (EPS) is a measure of the theoretical correlation between the N-series average and the population. A high EPS indicates that the full (N-tree) sample effectively captures a high proportion of the population variance. EPS depends on the mean between-tree correlation and the sample size as follows:

$$\mathrm{EPS} = \frac{N\bar{r}}{1+(N-1)\bar{r}}, \tag{14}$$

where N is the number of trees and $\bar{r}$ is the mean between-tree correlation of the core indices. The dependence of EPS on the between-tree correlation and N is evident in Table 2. Chronologies with EPS greater than 0.90, for example, have either a large sample size (e.g., Buckhorn Mountain), or high between-tree correlation (Cedar Butte Pine). The lowest value of EPS is 0.71 (Rockerville), indicating that only about 71 percent of the variance of the hypothetical "true" tree-ring series is captured by the N-tree chronology -- in this case a 5-tree chronology.

Because sample size n varies over time and is often much less than N in the early years of a chronology, it is useful to evaluate how the n-tree chronology correlates with the N-tree chronology for different values of n. The n-tree chronology is a subsample of the N-tree chronology. Wigley et al. (1984) recommend the subsample signal strength (SSS) as a statistic for evaluating the quality of the subsample:

$$\mathrm{SSS} = \frac{n(1+(N-1)\bar{r}}{N(1+(n-1)\bar{r}}, \tag{15}$$

where the quantities on the right-hand side are defined as in the expression for EPS. The last column in Table 2 lists the minimum sample size (number of trees) for which SSS exceeds 0.85, an arbitrary threshold suggested by Wigley et al. (1984). SSS is useful for evaluating the likely drop in climate-reconstruction accuracy as sample size drops below

the number of trees in the period used to calibrate the reconstruction model. The 0.85 threshold for SSS marks the sample size below which the loss in reconstruction variance explained would exceed 15%.

If a specific climate reconstruction has not been done, the SSS=0.85 threshold must be evaluated in the light of the corresponding value for EPS. For example, for the Bear Island chronology, the *n*-tree chronology explains 85% of the variance of the *N*-tree chronology when sample size reaches only two trees, but the *N*-tree chronology itself is poor (EPS=0.72) as an indicator of the hypothetical true tree-ring variation at the site.

A caveat to use of SSS and EPS for evaluating the statistical strength of a chronology is that the method assumes that all cores are equally valuable for the purpose at hand. The statistics could be misleading if one tree was clearly superior as a climate indicator. If so, averaging core indices together could increase the nonclimatic noise in the chronology.

Chronology Snapshots

This section contains contain text, data, and graphical summaries for each of the 27 chronologies. Summaries are presented on facing pages, with text and data on the left and graphics on the right. The elements of the summaries, in order from left to right and top to bottom across the two chronology pages, are described below. Results for the various chronologies are not discussed at length in this report. Some features are pointed out for chronology CSP, however, to illustrate interpretation.

Data Listing of Standard Chronology

The indices are listed a decade to a line at the left; the corresponding sample size (number of cores) is listed at the right. Indices have been scaled by multiplying by 100 and rounding to the nearest integer. For example, the standard chronology index for 1803 at CSP is 0.95, and the value is based on 4 cores. For brevity, only the standard chronology is listed in the graphical summaries. The standard and residual chronologies are included on the diskette.

Chronology Makeup

The "RING-WIDTH FILE" is the computer file containing the measured ring-width series on which ARSTAN was run to get the chronology. The prefix of the file name is the chronology code, and the suffix is "RWL". For example, the file CSP.RWL contains the ring widths for chronology CSP. The "RWL" files for all chronologies in this report are included on the diskette, in addition to the ARSTAN input control file that enables any researcher to duplicate computation of a chronology from its ring widths.

Below the name of the "RWL" file is listed is the number of ring-width series in the file, and the number of those not used in the chronology development. The "CORE MASK" indicates which ring-width series, if any, were deleted from the analysis, and whether a core is the first, second, third, and so forth core from a tree. The entries in the core mask are in the same order as the ring-width series in the "RWL" file. A "0" in the mask means the core was not used. A "1" means the core is the first core from a tree. A

"2" or higher means the core was a duplicate core from a tree. A user could therefore see from the core mask for CSP that:

Ring-width series 1, 3, and 5 were not used in the chronology

Cores 1,6,7,8,9, and 10 are "first" cores from a tree -- thus there are 6 trees

Core 4 is a "second" core from one of the trees marked with "1" in the core mask

Users of tree-ring chronologies should be keenly aware of any data manipulation that might bear on the intended application. For climatological applications, the most important manipulation is probably detrending -- the removal of the age trend. The detrending method determines the upper limit of the wavelength of climate variations that can be studied with the chronology. As discussed previously (see Methods), we standardized the ring-width series using the double-detrending option in program ARSTAN. Default detrending curve-types were first selected for the chronology. For example, the default might be a modified negative exponential followed by a spline of specified frequency response. If an entire ring-width series was used and the series was detrended by the selected chronology defaults, the core was classified as a "default" curve fit. If curve-fit methods other than the default were specified, or if the default curve types were specified but for a fitting interval other than the entire ring-width series, the core was classified as a "special" fit.

The "DEFAULT FIRST CURVE FIT" and "DEFAULT SECOND CURVE FIT" are the selected chronology default detrending functions used in double-detrending. Also listed are the number of "SPECIAL CURVE FITS", as defined above. The final entry is the number of cores and trees used in the final chronology. Unless all cores overlap in at least one year, this total number of cores is greater than the sample size at any given year in the chronology as shown in the chronology listing. For CSP, all cores do overlap: a total of 7 cores were used in the chronology, and the number of samples in the chronology listing is 7 cores for 1912-1961.

Remarks

Miscellaneous information is included here that might help potential users of the chronology to evaluate its suitability for climatological applications. For example, it is noted that the Burning Coal Vein chronology (#11) is a recollection of a chronology previously applied in a published reconstruction of precipitation. Information on site-type and on site characteristics of particularly old trees is also commonly included in this section.

Nearby Climate Stations

At the top of the graphics summary page is a list of the nearest three Historical Climatology Network (Quinlan et al. 1987) precipitation stations to the tree-ring site. Annual precipitation averaged over these stations for the period 1919-1989 was used in correlation and modeling studies aimed at quantifying the precipitation signal in the chronology. If fewer than three stations are within a 100-km radius of the site, only those

within the radius are listed and are used in the analysis. For chronologies built from multiple sites, the listed distances were computed from the site with the same 3-letter code as the chronology (e.g., site HNK for the Hankins Group chronology). .

Normal Probability Plot

The normal probability plot graphically shows how closely the empirical cumulative distribution function (cdf) of the standard chronology resembles the cdf of a normally distributed variable with the same mean and variance. The plot is based on the full length of the chronology. The theoretical normal cdf is plotted as a straight dash-dot line; the cdf of the standard chronology is plotted as "+" symbols. Departure of the empirical plot from the straight line means that the standard chronology departs from normality. For example, the plot for chronology CSP (#1) indicates three characteristics of the chronology: (1) approximate normality when the index is between 0.75 and 1.5, (2) greater departures toward high index than expected for a normal distribution, and (3) smaller departures toward low index than expected for a normal distribution. This pattern is consistent with a positively skewed variable.

Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF)

The ACF (solid) and PACF (dotted) are plotted for the full-length standard chronology at lags 1-20 years. Also plotted are the large-lag 95% confidence bands for the ACF (Box and Jenkins 1976). The ACF is a measure of persistence in the chronology -- the tendency for large values of the index to follow large values, and small values to follow small values. The patterns of decay of the ACF and PACF indicate plausible forms of simple autoregressive-moving average (ARMA) models that might be invoked to explain the persistence (Box and Jenkins 1976). For example, for chronology CSP, the ACF decays exponentially and the PACF abruptly drops near zero after lag 1 -- patterns that suggest a first-order autoregressive process. The lag-1 ACF value for site CSP is about 0.74 (also see Table 2), indicating that more than 50% of the variance of the standard chronology could be predicted by a linear regression model using only the previous year's chronology value as a predictor.

Box-plot Summaries of Skew and Lag-1 Autocorrelation of Core Indices

Box plots graphically summarize the center and spread of a distribution of a variable, and display the occurrence of outliers (Cleveland 1993). Box plots are based on quantiles of the data. The 0.1 quantile is the value exceeded 90% of the time; the 0.2 quantile is the value exceeded 80%; the 0.5 quantile is the median; and so forth.

The scale of the variable is marked along the left axis of the plot. The horizontal line in the box marks the median. The lower and upper ends of the box mark the 0.25 and 0.75 quantiles, also called the lower and upper quartiles. The distance between the 0.25 and 0.75 quantiles is called the interquartile range, *r*. If r is small, the data are packed tightly together -- the spread is small. Conversely, if r is large, the data are spread widely apart.

The dashed vertical lines extending from the top and bottom of the box end at the *adjacent values*. These lines are also referred to as the "whiskers". The upper adjacent value is the largest observation within 1.5r of the upper quartile; the lower adjacent value is the smallest observation within 1.5r of the lower quartile. For Gaussian distributed data, 99.3% of the data should fall within the whiskers. Values outside the whiskers are outliers, flagged by a "+" symbol.

Box plots are shown for two statistics of the core indices -- skew and first-order autocorrelation coefficient, *r(1)*. The individual skew and *r(1)* values are computed on the full lengths of the core indices. The sample size (number of cores, *N*) on which the box plots are based is annotated at the lower left. The value of *N* might not match the number of cores listed in the standard-chronology sample size or the "Chronology Makeup" for two reasons: (1) for chronologies based on few cores, we have sometimes included for the box-plot computations cores not used in the chronology, and (2) for chronologies based on many cores, we have sometimes selected a subset of long core indices for the box plots. To facilitate comparison of the various chronologies, we have restricted the y-axis to the range -1 to +1. Some box plots for skew are consequently truncated, but still serve to demonstrate the general pattern of internal consistency of skew among the various core indices.

Interpretation can best be illustrated by example. Consider the box plots for chronology #1 (CSP). The sample size is only 10 cores for this example. The box plot for skew clearly indicates positive skewness as a general trait. The median of the 10 computed skew values is close to 0.8, but the spread of skew among the various core indices is large: the lower quartile is about 0.2, and at least one core-index series is slightly negatively skewed.

The box plot for *r(1)* shows that except for one outlier, the lag-1 autocorrelation of the core indices is positive, and that the distribution of the core-index *r(1)* is tightly clustered on 0.7. This information is consistent with the previously discussed ACF plot for the standard chronology, which indicated a first-order autocorrelation of about 0.75. The solitary "+" symbol below the *r(1)* box plot indicates that one core index series went against the grain with a slightly negative first-order autocorrelation.

Time Series Plot of Smoothed Standard Chronology

The smoothed standard chronology is plotted as solid line, and the number of cores in the chronology as a dashed line. The scale for the chronology is marked on the left axis, the scale for the chronology on the extended right axis. The chronology has been smoothed with a 5-weight binomial filter with weights 1/16, 1/4, 3/8, 1/4, 1/16. The time series plot shows excursions of low-growth and high-growth over the full length of the standard chronology.

For example, the time series plot for CSP shows an upward trend in tree-ring index from a low in the late 1930s to the present. The plot also shows periods of low growth centered on the early 1820s and about 1870. A period of very high growth, with a smoothed tree-ring index of 1.8, occurs in the late 1700s, but the sample size is only about half that in the 20th century.

Scatterplot, Tree-Ring vs Climate

A simple graphical summary of the linear relationship between precipitation and the tree-ring index is the scatterplot of the standard chronology against the percentage of normal precipitation, averaged over the (up to) three climate stations in the 100 km search radius. The period for analysis was 1919-89. The scatterplot is shown at the lower left of the graphics page, along with the best least-squares fit straight line for the relationship. The R^2 value for the linear relationship is annotated at the top of the figure. The plot for chronology CSP, for example, suggests a very weak positive relationship between tree-ring index and annual precipitation. Only 12% of the precipitation variance is explained by the linear relationship. The shape of the cluster of points gives no hint of nonlinearity.

One-Step Ahead Predictions of Tree-Ring Index

A simple scatterplot of the tree-ring series in year *t* against the precipitation in year *t* cannot capture the lagged-response relationships characteristic of a dynamic system. Accordingly we have applied linear dynamic modeling to the system, as described in the Methods section. The output from the models is the standard tree-ring chronology. The input is the annual (September-August total) precipitation averaged over the nearest HCN climate stations in the 100 km search radius around the tree-ring site. The calibration period for modeling is 1919-89. The modeling results are summarized in the figure at lower right on the graphics page.

The annotated information consists of (1) orders of best-fit OE and ARX models, (2) final prediction error (FPE) of the best-fit model, and (3) reduction-of -variance (RV) statistic summarizing accuracy of the fit. The quantities FPE and RV are defined in the Methods section. Most useful for climatological evaluation is the RV-statistic for the OE model structure. This RV statistic essentially measures the fraction of chronology variance predictable from past and current values of the precipitation series. RV for the OE model is higher than the R^2 in the scatterplot at left because the scatterplot regression does not consider lag relationships. RV for the OE model is generally lower than RV for the ARX model because the ARX model uses past values of the chronology in addition to past and present values of precipitation to predict the current value of the chronology.

Three time series plots are shown in the figure. The solid line is the standard chronology -- the observed output. The dashed line is the one-step-ahead prediction of the chronology using precipitation as model input. The dotted line is the one-step-ahead prediction of the chronology using precipitation and past values of the chronology as model input.

Several features of the modeling results for the CSP chronology are noted here to illustrate the interpretation. The RV-statistic indicates that only about 25% of the variance of the chronology can be attributed to past and current values of precipitation. This percentage is a slight gain over the 12% noted in the scatterplot for a no-lag relationship. The best-fit OE model is relatively simple -- OE(1,1), which could be re-formulated to express the chronology in terms of white noise superimposed on climate input whose importance diminishes geometrically back in time from year *t* (Ljung 1987).

The predicted chronology by this model tracks low-frequency features of the actual chronology fairly well in some periods but poorly in other periods. The most notable shortcoming is the failure to track to the upward trend in the observed chronology since about 1975.

The ARX model for the CSP chronology , on the other hand, is extremely accurate in the one-step-ahead prediction. This accuracy is to be expected given the high autocorrelation in the chronology. The selected order is AR(2,1), meaning that the prediction for the tree-ring index in year *t* depends explicitly on (1) the index in years *t-1* and *t-2*, and (2) the precipitation in the current year.

****

Figure 4. Two-page chronology snapshots. The summaries described above are included on pages 28-81. The order of presentation is the same as the numbering of chronologies in Table 2.

1 CSP Custer State Park SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1775						130	122	145	112	127
1780	135	119	86	87	79	55	114	77	117	113
1790	129	93	142	215	199	158	140	125	99	119
1800	75	92	95	88	86	102	116	90	66	58
1810	71	80	73	106	106	71	92	101	80	95
1820	64	76	56	45	37	40	51	66	81	73
1830	113	97	127	116	115	128	98	108	117	86
1840	116	104	79	88	141	137	119	111	121	156
1850	154	164	143	169	134	96	83	91	85	84
1860	73	73	98	73	74	58	73	94	73	72
1870	65	55	49	55	70	57	55	57	61	77
1880	83	79	89	73	87	92	89	112	112	113
1890	111	135	147	113	101	103	100	95	101	103
1900	102	129	123	129	141	191	124	149	138	120
1910	79	84	141	117	85	75	102	117	112	116
1920	107	110	135	130	111	128	131	105	129	128
1930	104	82	131	116	95	115	84	72	66	68
1940	58	75	77	76	76	78	68	72	63	81
1950	86	75	76	76	77	72	65	104	99	102
1960	75	74	88	90	98	111	85	91	92	100
1970	102	110	129	115	84	102	83	104	127	131
1980	107	127	146	122	128	95	119	117	115	118
1990	94									

Number of samples

	0	1	2	3	4	5	6	7	8	9
1775						1	1	1	1	1
1780	1	1	2	2	2	2	2	2	2	2
1790	2	2	2	2	3	4	4	4	4	4
1800	4	4	4	4	4	4	4	4	4	4
1810	4	4	4	4	4	4	4	4	4	4
1820	4	4	4	4	4	4	4	4	4	4
1830	4	4	4	4	4	4	4	4	4	4
1840	4	4	4	4	4	4	4	4	4	4
1850	4	4	4	4	4	4	4	4	4	4
1860	4	4	4	4	4	4	4	4	4	4
1870	4	4	4	4	4	4	4	4	4	4
1880	4	4	4	4	4	4	4	4	4	4
1890	4	4	4	4	4	4	4	4	4	5
1900	5	5	5	5	5	5	5	5	6	6
1910	6	6	7	7	7	7	7	7	7	7
1920	7	7	7	7	7	7	7	7	7	7
1930	7	7	7	7	7	7	7	7	7	7
1940	7	7	7	7	7	7	7	7	7	7
1950	7	7	7	7	7	7	7	7	7	7
1960	7	7	6	6	6	6	6	6	6	6
1970	6	6	6	6	6	6	6	6	6	6
1980	6	6	6	6	6	6	6	6	6	6
1990	5									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: CSP.RWL
10 SERIES IN FILE, 3 NOT USED
CORE MASK: 1234567890
0102011111
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
2 SPECIAL (NON-DEFAULT) CURVE FITS
7 CORES, 6 TREES IN FINAL CHRONOLOGY

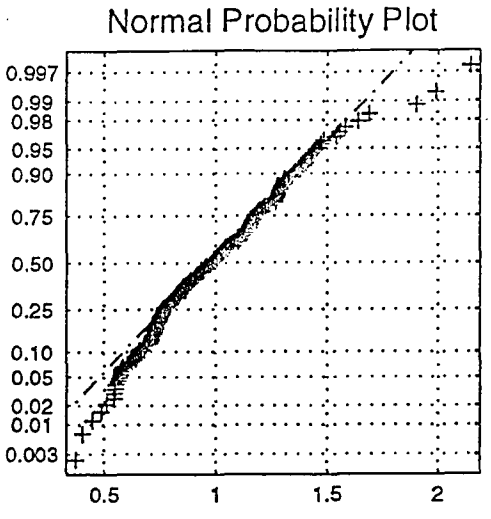
REMARKS

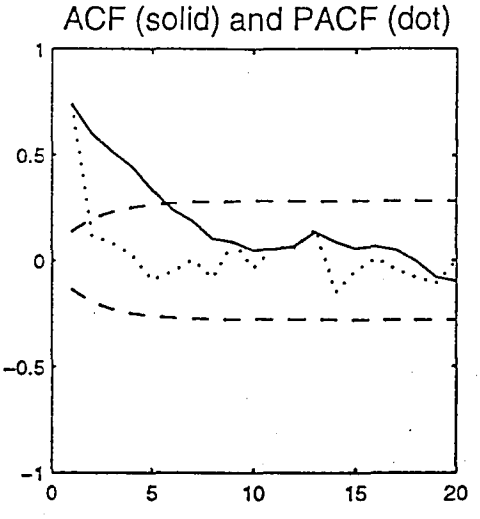
Custer State Park in the southern Black Hills, 16 km southeast of Custer, South Dakota. Chronology species -- bur oak. Site types range from rocky upland to creekside. According to a local biologist, this area was cut over years ago. A dense stand of ponderosa pine is currently being cut. Center rot is common in the bur oak -- evident from ends of trees cut recently for a logging road.

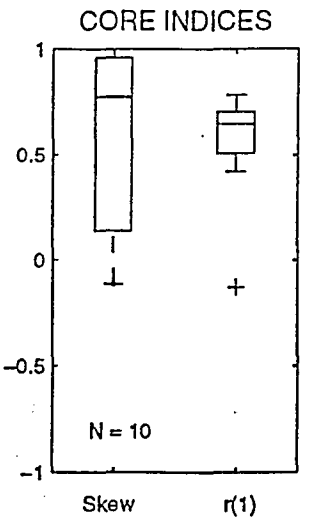
CUSTER STATE PARK

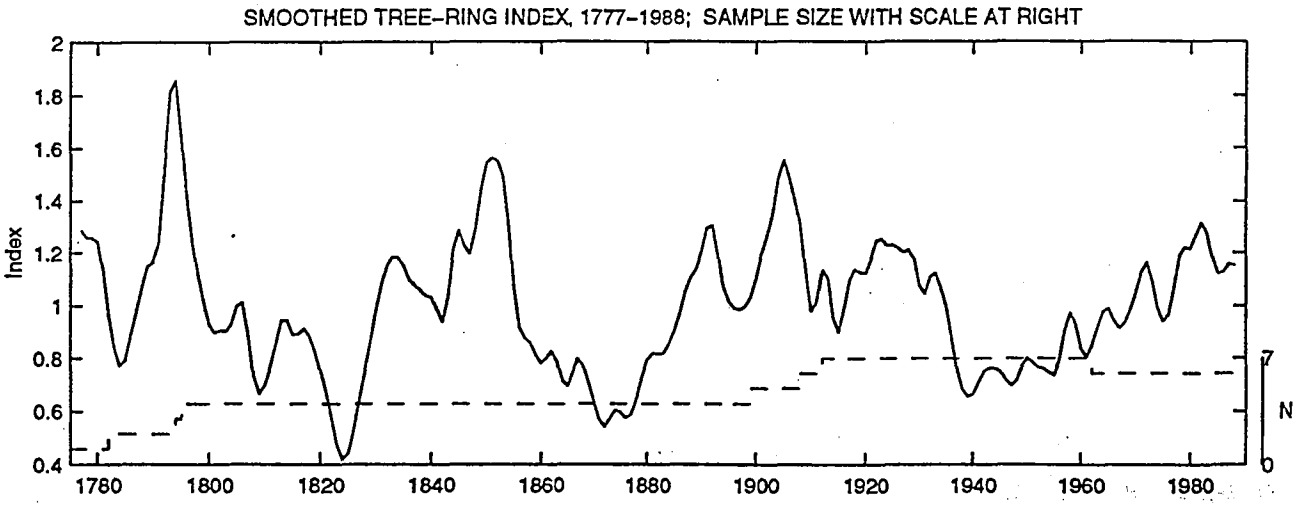
Climate Stations and Distances to Tree-Ring Site:

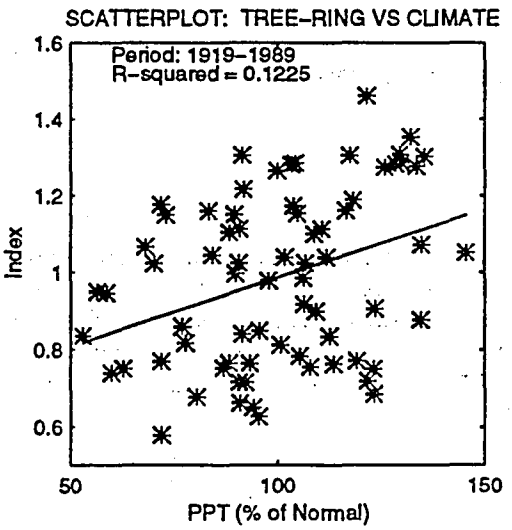
	State	ID	Distance (km)
HOT SPRINGS	SD	39044007	36
RAPID CITY	SD	39056947	38
NEWCASTLE	WY	48076660	67

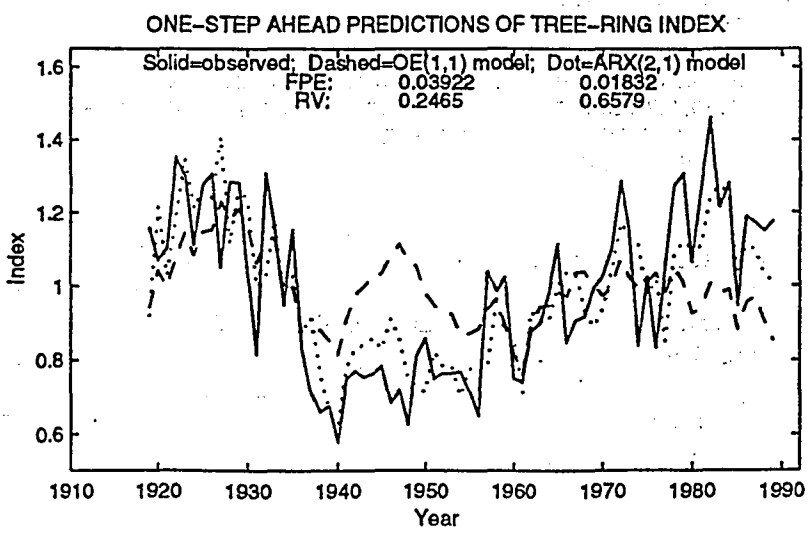












2 THO Thompson SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1747								126	98	39
1750	54	60	17	26	86	142	49	55	64	81
1760	166	155	93	127	148	196	162	159	157	60
1770	49	112	97	87	107	84	85	128	145	106
1780	142	99	70	98	149	77	94	55	94	55
1790	74	56	76	141	142	113	96	153	86	95
1800	42	121	118	126	116	75	107	58	80	81
1810	108	145	119	144	53	52	60	97	91	99
1820	95	114	95	87	106	102	153	141	121	70
1830	127	71	94	110	124	110	90	113	78	94
1840	135	138	39	110	109	102	114	104	93	84
1850	100	133	116	139	108	102	60	108	104	94
1860	100	115	104	104	91	101	87	76	90	97
1870	73	65	108	77	86	105	105	111	137	130
1880	111	89	99	107	99	111	90	101	85	84
1890	107	102	109	117	103	106	87	75	92	85
1900	52	88	107	81	90	119	91	121	96	138
1910	70	85	97	99	85	52	101	101	103	86
1920	131	70	152	108	122	125	112	122	132	118
1930	112	58	116	133	83	82	75	107	111	99
1940	83	100	146	79	73	107	87	57	90	100
1950	119	78	79	114	104	123	124	95	122	97
1960	82	98	119	91	159	178	127	66	102	120
1970	116	86	122	91	83	58	84	103	118	116
1980	58	101	99	82	89	75	96	91	75	110
1990	122									

Number of samples

Date	0	1	2	3	4	5	6	7	8	9
1747								1	1	1
1750	1	1	1	1	1	1	1	1	1	1
1760	1	1	1	1	1	1	2	2	2	2
1770	2	2	2	2	2	2	2	2	2	2
1780	2	2	2	2	2	2	2	2	2	2
1790	2	2	2	2	2	2	2	2	2	2
1800	2	2	2	2	2	2	2	2	2	2
1810	2	2	2	2	2	2	2	2	2	2
1820	2	2	2	2	2	2	2	2	2	2
1830	2	2	2	2	2	2	2	2	2	2
1840	2	2	2	2	2	2	2	2	2	2
1850	2	2	2	2	2	2	2	2	2	2
1860	2	2	2	2	2	2	2	2	2	2
1870	2	2	2	2	2	2	2	2	2	2
1880	2	2	3	4	4	4	4	4	4	4
1890	4	4	4	4	4	4	3	3	3	3
1900	3	3	4	4	4	4	4	4	4	4
1910	4	4	5	5	5	5	5	5	5	5
1920	5	5	5	5	5	5	5	5	5	5
1930	5	5	5	5	5	5	5	5	5	5
1940	5	5	5	5	5	5	5	5	5	5
1950	5	5	5	5	5	5	5	5	5	5
1960	5	5	5	5	5	5	5	5	5	5
1970	5	5	5	5	5	5	5	5	5	5
1980	5	5	5	5	5	5	5	5	5	5
1990	5									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: THO.RWL
9 SERIES IN FILE, 3 NOT USED
CORE MASK: 123456789
001201121
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT 100% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
2 SPECIAL (NON-DEFAULT) CURVE FITS
6 CORES, 4 TREES IN FINAL CHRONOLOGY

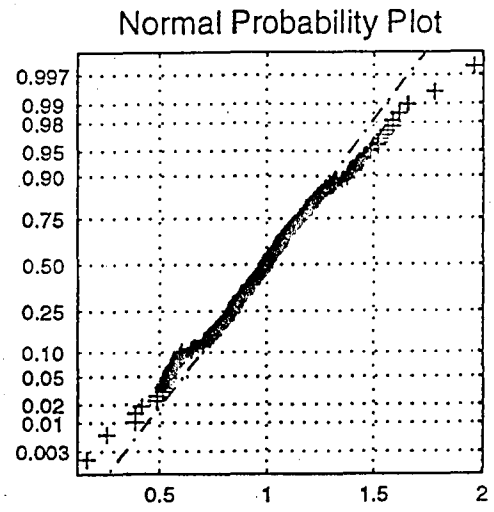
REMARKS

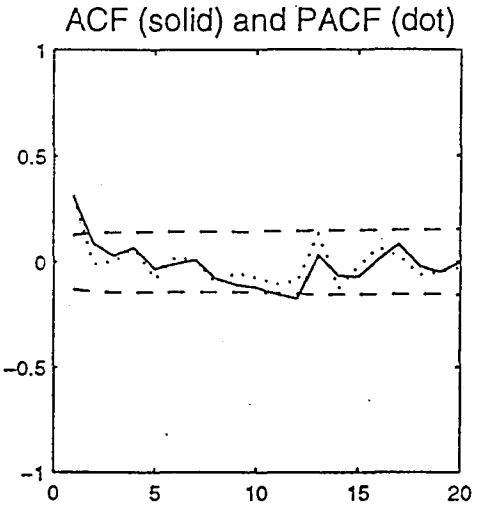
Private land near the northern end of the Black Hills, 10 km southwest of Belle Fourche, South Dakota. Chronology species -- bur oak. Samples are from terrace and hillside above creek. The oldest tree (inner ring, 1747) is growing solitary, on level ground, in an irrigated alfalfa field. The last 100 years of growth in this tree are probably distorted by irrigation. According to a local rancher, the tree was used to hang thieves in the 1800s. Rot is common in the sampled trees. Cores from site MFH were considered for merging into this chronology, but were not used because of uncertain crossdating.

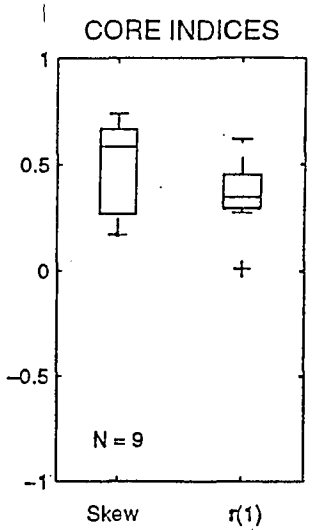
THOMPSON

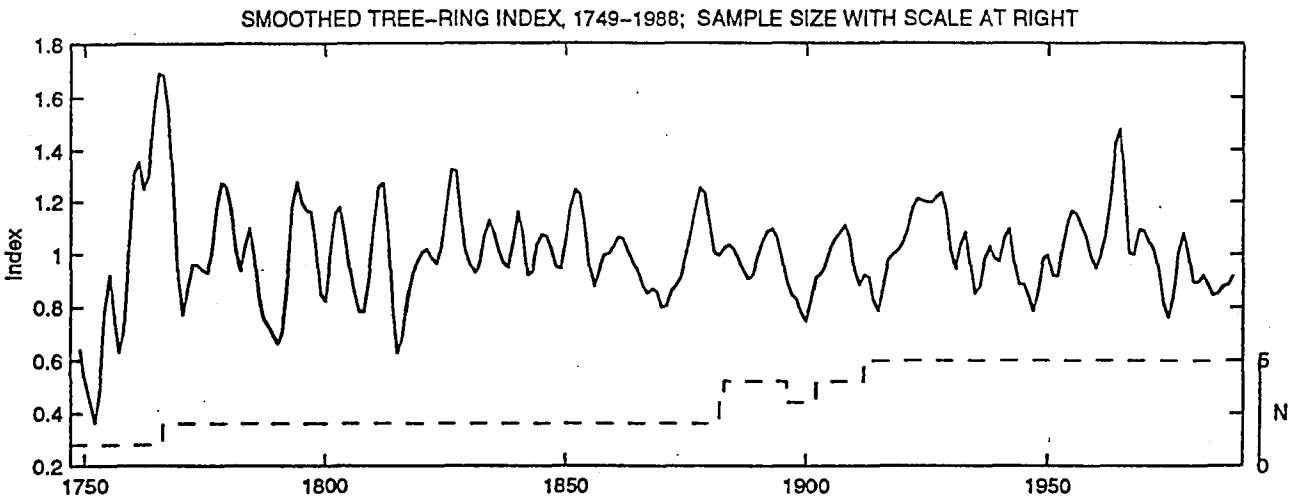
Climate Stations and Distances to Tree-Ring Site:

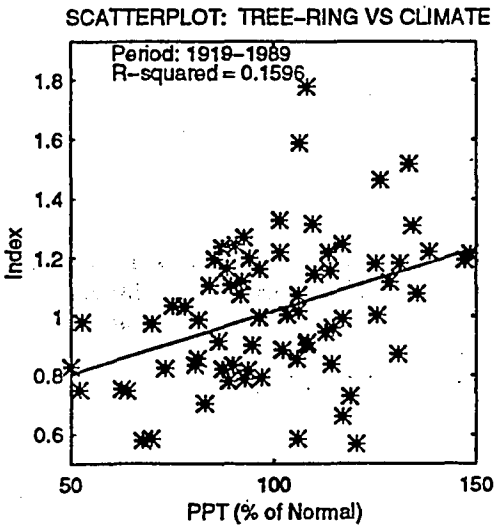
	State	ID	Distance (km)
COLONY	WY	48061905	42
RAPID CITY	SD	39056947	81
NEWCASTLE	WY	48076660	84

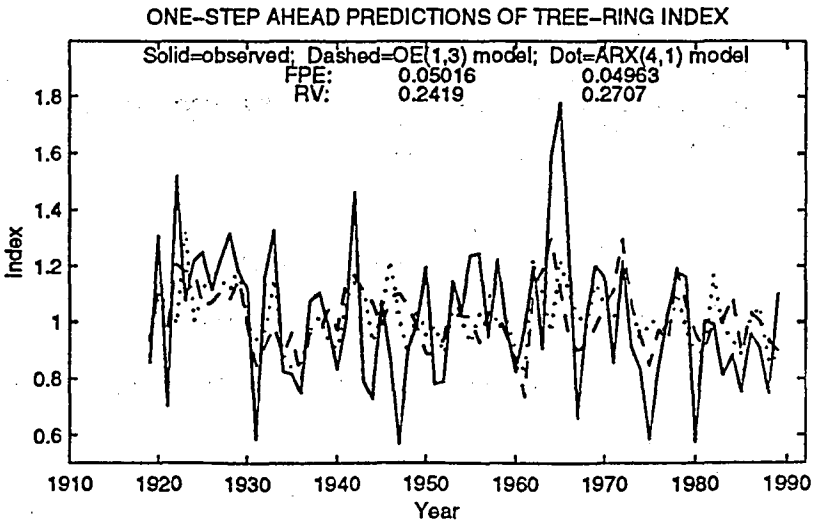












3 FDF Frawley Dairy Farm SD

	Tree-Ring Indices									Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1807								177	142	115								1	1	1
1810	143	124	152	115	83	72	71	71	76	75	1	1	1	1	1	1	1	1	1	1
1820	54	75	65	102	79	81	89	107	123	132	1	1	1	2	2	2	2	2	2	2
1830	100	75	117	131	103	87	138	111	92	77	2	2	2	2	2	2	2	2	2	2
1840	106	141	70	68	136	104	100	98	102	89	2	2	2	2	2	2	2	2	2	2
1850	112	135	68	67	92	84	126	133	135	134	2	2	2	2	2	2	2	2	2	2
1860	119	101	129	88	84	62	57	59	68	71	2	2	2	2	3	4	4	4	4	4
1870	79	61	80	75	77	69	92	71	103	138	4	4	4	4	4	4	4	4	4	4
1880	102	86	117	96	109	151	77	123	126	77	5	6	6	6	6	6	6	7	7	7
1890	93	117	140	115	141	128	103	87	85	84	7	7	7	7	9	10	10	10	10	10
1900	63	65	91	95	124	109	87	102	93	112	10	10	10	10	10	10	10	10	10	10
1910	77	70	88	111	95	66	112	113	117	118	10	10	10	10	10	11	11	11	11	11
1920	123	102	150	134	135	136	136	141	138	139	11	11	11	11	11	11	11	11	11	11
1930	95	68	119	127	85	97	72	52	57	67	11	12	12	12	12	12	12	12	12	12
1940	55	63	124	91	74	115	70	97	72	115	12	12	12	12	12	12	12	12	12	12
1950	107	74	73	128	122	105	92	106	104	86	12	12	12	12	12	12	12	12	12	12
1960	71	61	72	69	123	142	102	88	112	152	12	12	12	12	12	12	12	12	12	12
1970	126	106	130	108	92	86	96	107	130	122	12	12	12	12	12	12	12	12	12	12
1980	82	92	115	97	98	82	125	106	89	99	12	12	12	12	12	12	12	12	12	12
1990	84										12									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: FDF.RWL
12 SERIES IN FILE, 0 NOT USED
CORE MASK: 123456789012
121212121212
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT WAVELENGTH OF 107 YR
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
1 SPECIAL (NON-DEFAULT) CURVE FIT
12 CORES, 6 TREES IN FINAL CHRONOLOGY

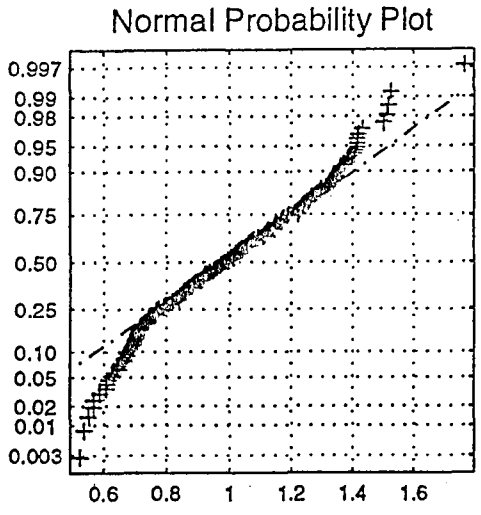
REMARKS

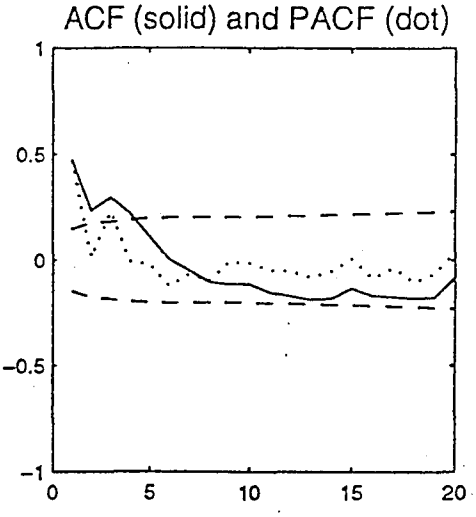
Private land at the northern edge of the Black Hills, 3 km northwest of Whitewood, South Dakota. Chronology species -- bur oak. A mixture of upland and lowland trees were sampled. Trees 1-3 are from an upland site on hillside with a southwest aspect. Trees 4-6 are from a nearby level lowland site along a creek. Trees from the lowland site are much larger than from the upland site: diameter at breast height (DBH) of upland trees is less than 32 cm; DBH of lowland trees is 59-82 cm. No noticeable difference in ease of crossdating was found between the site types.

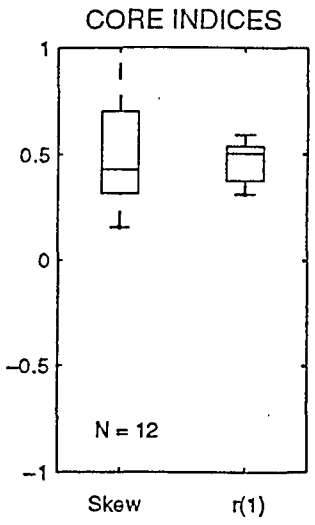
FRAWLEY DAIRY FARM

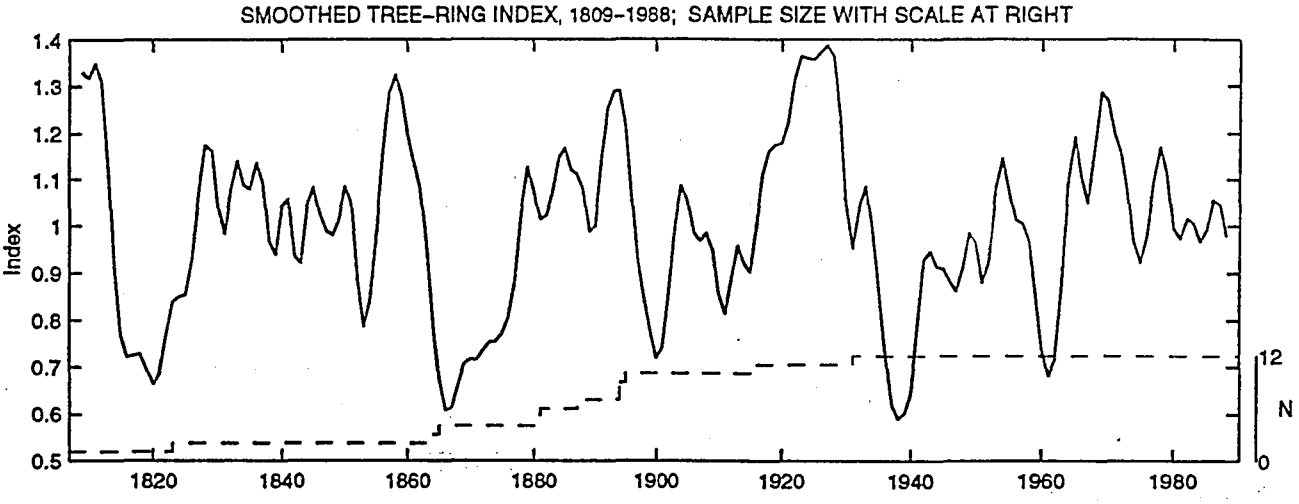
Climate Stations and Distances to Tree-Ring Site:

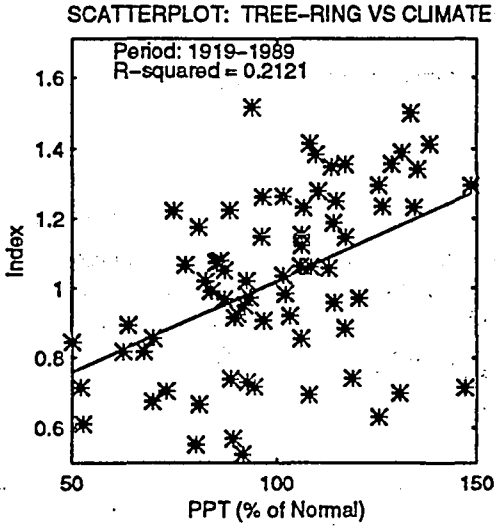
	State	ID	Distance (km)
RAPID CITY	SD	39056947	54
COLONY	WY	48061905	66
NEWCASTLE	WY	48076660	81

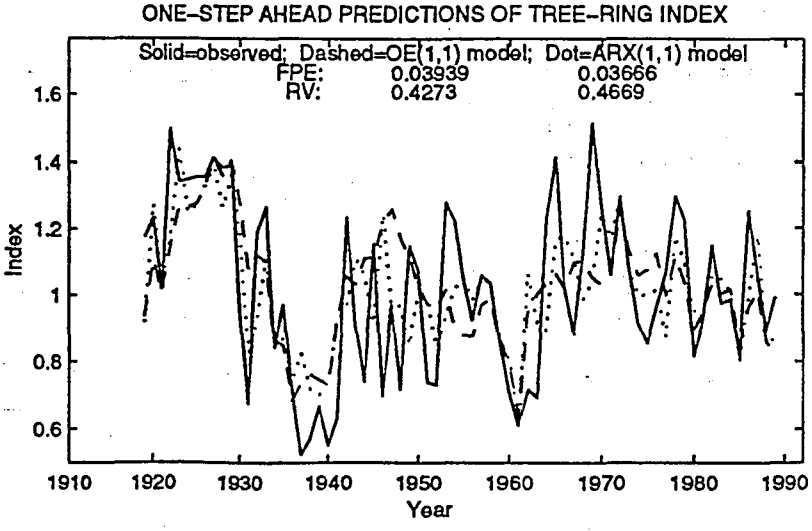












4 CRY Crystal Cave SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1833				130	133	128	103	106	112	125
1840	85	129	92	97	58	129	83	86	57	78
1850	92	139	67	97	124	98	101	81	82	73
1860	117	122	146	78	111	80	84	117	171	101
1870	90	69	91	89	73	70	83	90	110	101
1880	126	117	184	129	86	80	60	95	114	105
1890	109	101	127	102	58	88	69	57	70	81
1900	50	84	116	125	136	93	108	137	117	96
1910	76	64	116	114	103	72	100	93	115	81
1920	60	92	131	124	104	133	137	91	78	103
1930	104	94	133	118	94	121	80	100	95	78
1940	82	94	125	88	81	129	128	116	104	101
1950	91	93	84	111	76	82	111	137	103	100
1960	105	71	72	81	103	115	83	70	100	80
1970	112	93	106	97	87	108	116	110	131	112
1980	84	100	116	135	114	71	104	113	79	95
1990	104									

Number of samples

0	1	2	3	4	5	6	7	8	9
			1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	3	3
4	4	4	5	5	5	5	5	5	5
6	6	6	7	9	9	9	9	10	10
10	11	11	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12
14	14	14	14	14	14	14	14	14	14
14	14	14	14	14	13	13	13	13	13
13	13	13	13	13	13	13	13	13	13
13	13	13	13	13	13	13	13	13	13
13									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: CRY.RWL
18 SERIES IN FILE, 4 NOT USED
CORE MASK: 123456789012345678
012121200123123O1
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
15 CORES, 7 TREES IN FINAL CHRONOLOGY

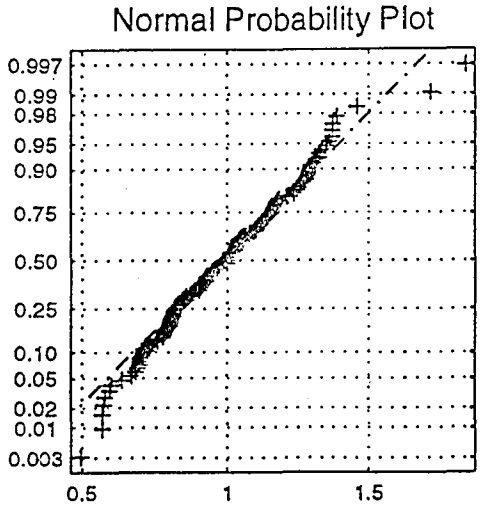
REMARKS

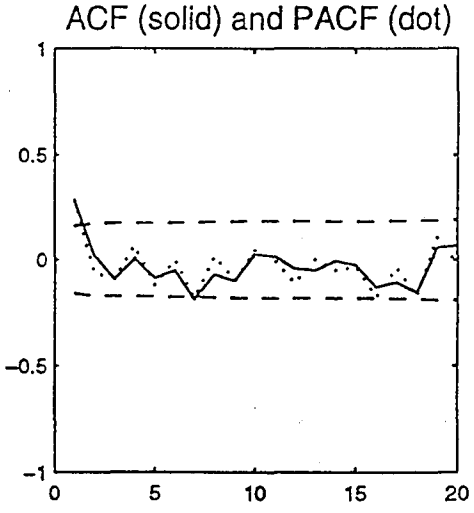
Private land in the central Black Hills, 14 km south of Rapid City, South Dakota. Chronology species -- bur oak. Samples were taken from upland and lowland trees. The ground slope for upland samples was only 10-15 degrees. Two additional bur oak cores (5c and 5d) were collected from tree 5 at later date (9-30-92) than the main collection. Core samples were also taken from four ponderosa pine trees at the site. The sampled pondersa pine turned out to be young -- inner rings in the early 1900s.

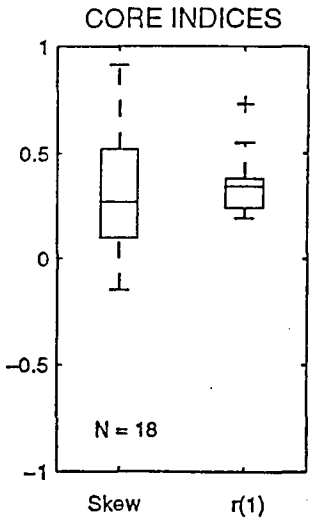
CRYSTAL CAVE

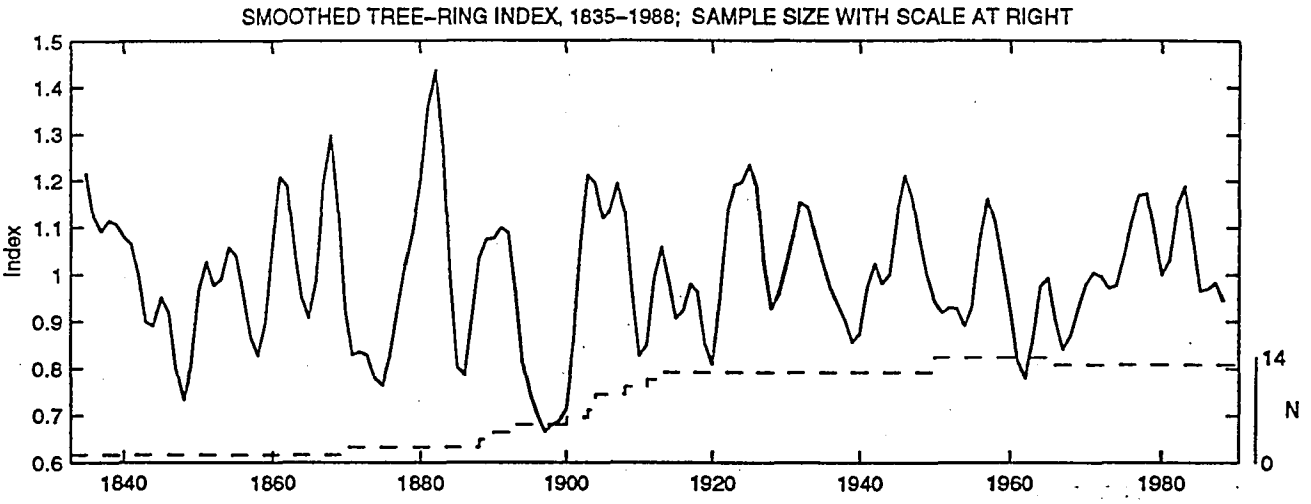
Climate Stations and Distances to Tree-Ring Site:

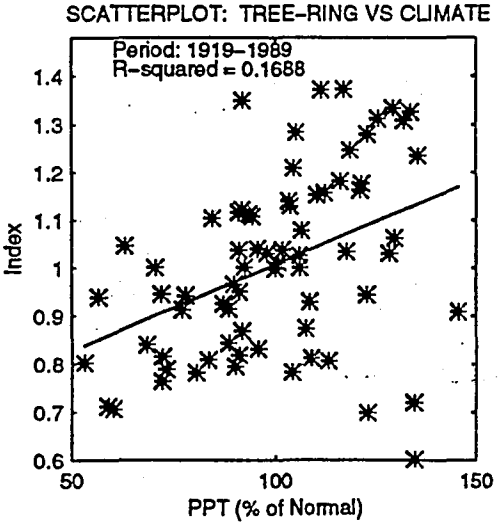
	State	ID	Distance (km)
RAPID CITY	SD	39056947	14
HOT SPRINGS	SD	39044007	60
NEWCASTLE	WY	48076660	74

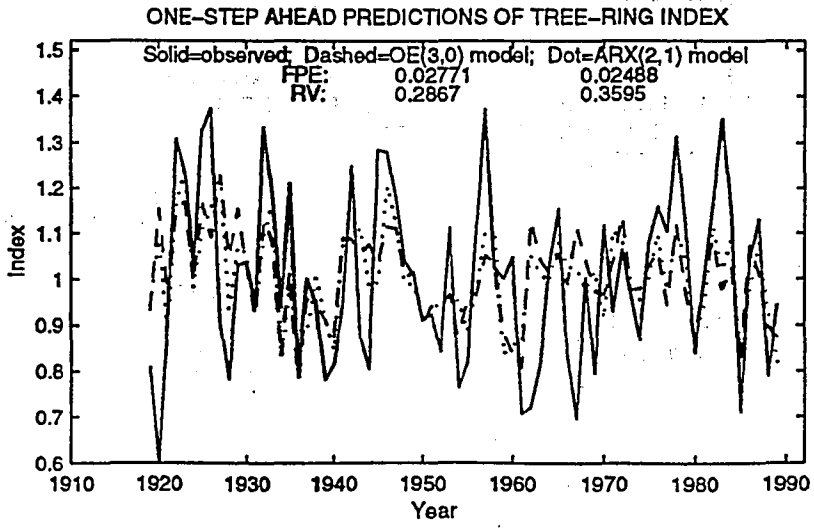












5 FRW Frawley Oak SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1892			137	105	142	177	69	101	96	109
1900	41	56	64	88	112	91	68	120	125	103
1910	85	47	124	89	67	86	145	115	93	84
1920	134	49	133	113	160	141	127	173	124	150
1930	90	61	143	132	51	85	51	45	41	42
1940	47	82	143	101	85	136	102	145	88	132
1950	107	73	65	143	110	114	75	133	98	66
1960	60	44	75	71	121	140	94	72	104	119
1970	128	100	129	106	81	89	106	102	138	116
1980	66	86	128	92	139	75	120	106	78	91
1990	99									

Number of samples

0	1	2	3	4	5	6	7	8	9
		1	1	1	2	3	3	3	3
3	3	3	3	3	3	4	4	5	5
5	5	5	5	5	5	5	5	5	5
5	5	5	6	6	6	6	7	7	7
7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7
7	7	7	7	7	7	7	7	7	7
7									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: FRO.RWL
12 SERIES IN FILE, 5 NOT USED
CORE MASK: 123456789012
012301200120
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT WAVELENGTH OF 75 YR
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
7 CORES, 3 TREES IN FINAL CHRONOLOGY

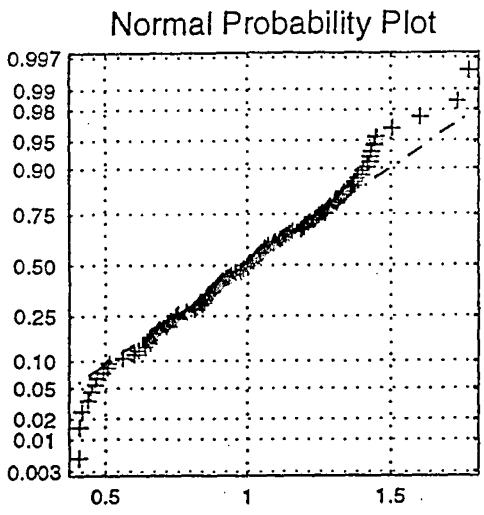
REMARKS

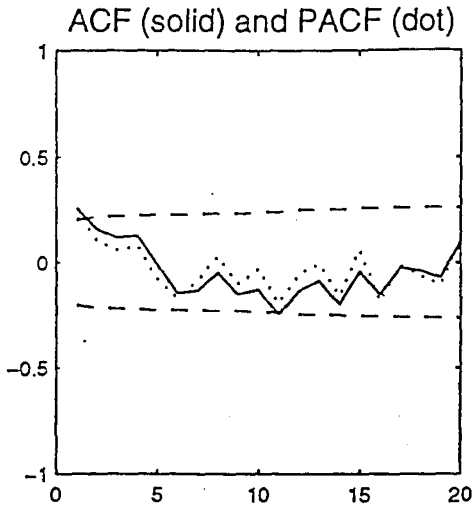
Private land at the northern edge of the Black Hills, 3 km northwest of Whitewood, South Dakota. Chronology species -- bur oak. This site is directly across Interstate 90 from site FDF. Samples are from a grassy hillside and the banks of a small dry drainage. The aspect is mainly south or southwest, with variable slope angle to 40 degrees. Three ponderosa pine were also sampled, but the crossdating was too uncertain for development of a chronology.

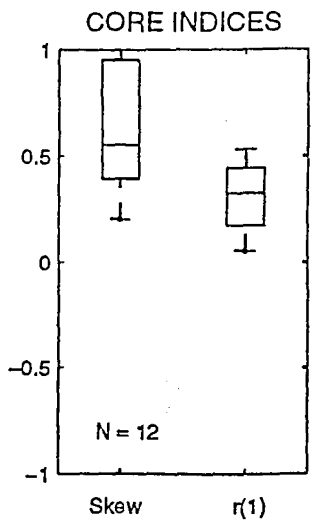
FRAWLEY OAK

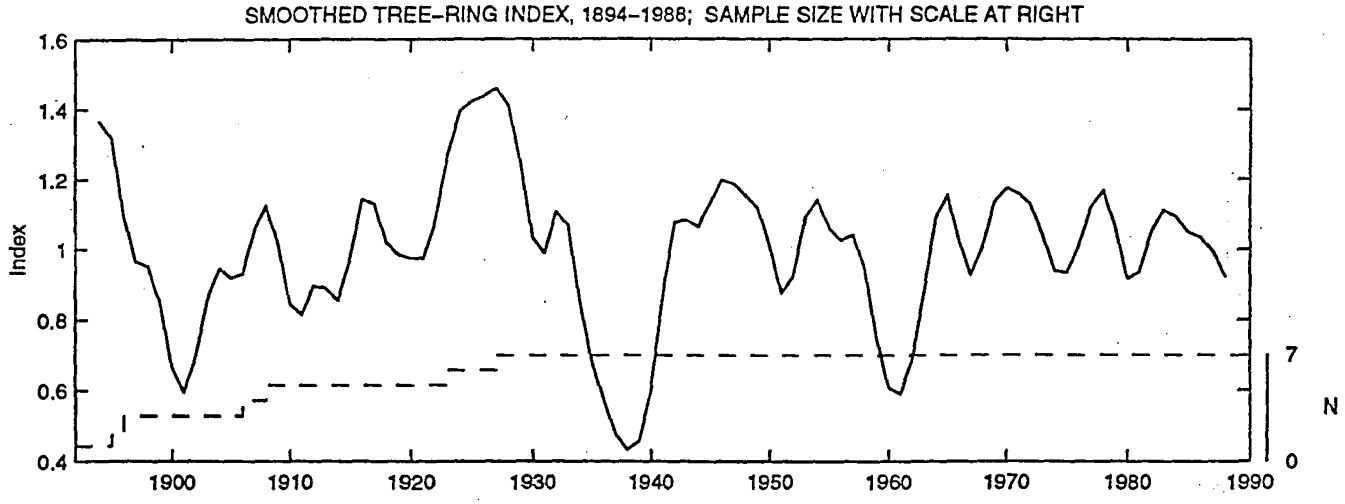
Climate Stations and Distances to Tree-Ring Site:

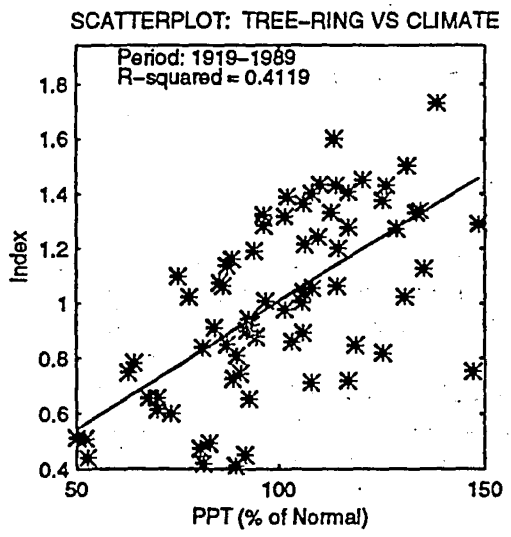
	State	ID	Distance (km)
RAPID CITY	SD	39056947	56
COLONY	WY	48061905	65
NEWCASTLE	WY	48076660	83

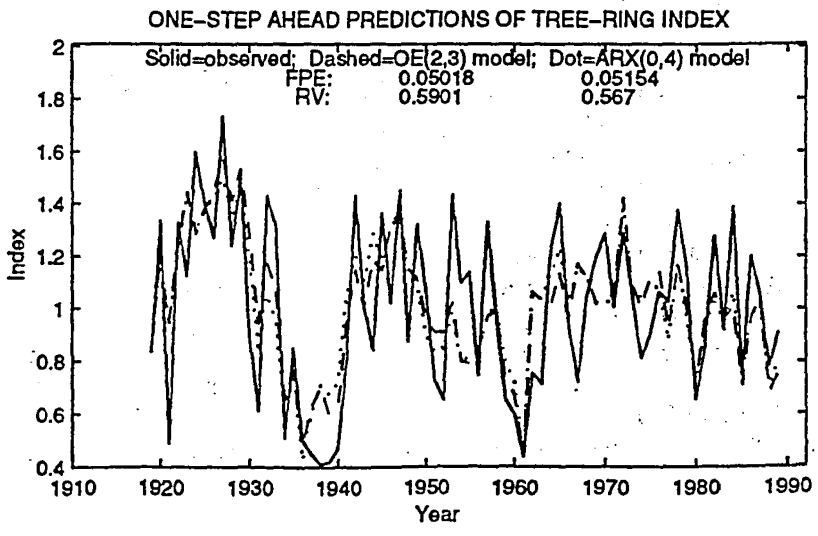












6 ENC Eagle Nest Canyon SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1651		82	97	62	31	77	100	152	155	13
1660	5	15	58	34	74	136	191	126	109	151
1670	133	83	138	144	72	126	110	59	66	75
1680	107	155	175	190	203	161	204	235	143	99
1690	76	122	143	101	142	153	107	58	38	97
1700	87	93	138	97	79	92	67	95	94	117
1710	89	36	28	75	95	92	116	35	8	32
1720	53	40	67	103	89	61	90	134	169	176
1730	140	97	104	191	135	99	111	174	201	169
1740	250	91	100	109	110	144	153	133	58	41
1750	93	67	82	68	116	84	19	44	9	38
1760	19	46	41	72	79	76	141	173	153	92
1770	101	123	52	66	98	119	86	104	242	183
1780	207	119	70	80	96	58	85	78	64	38
1790	98	104	103	171	97	118	100	134	52	76
1800	55	96	111	99	99	118	139	143	31	66
1810	52	63	80	85	80	57	51	20	13	55
1820	58	87	48	20	41	78	113	118	180	186
1830	186	133	186	199	156	153	110	121	100	86
1840	114	100	106	129	176	143	132	153	53	137
1850	117	158	95	151	146	56	69	36	93	35
1860	53	81	78	38	45	17	69	81	99	89
1870	33	58	65	70	40	47	37	83	104	213
1880	144	102	156	139	104	133	86	45	100	70
1890	68	99	80	55	78	85	98	88	103	122
1900	78	75	111	111	81	86	141	195	153	156
1910	149	55	132	133	92	154	168	104	128	77
1920	87	107	149	139	163	126	125	186	125	153
1930	185	92	131	100	56	91	32	69	58	13
1940	56	68	90	68	95	118	134	153	102	50
1950	78	66	89	105	110	51	78	108	88	49
1960	81	31	79	75	36	107	93	108	96	96
1970	89	127	147	120	90	139	140	56	122	134
1980	21	92	123	130	123	93	160	109	88	99
1990	95									

Number of samples

Date	0	1	2	3	4	5	6	7	8	9
1651		1	1	1	1	1	1	1	1	1
1660	1	1	2	2	2	2	2	2	2	2
1670	2	2	2	2	2	2	3	3	3	3
1680	3	3	5	5	5	5	5	6	6	6
1690	6	6	6	6	6	6	8	8	8	8
1700	8	10	10	10	11	11	12	12	12	13
1710	13	13	13	13	13	13	13	13	13	13
1720	13	13	13	13	13	13	13	13	13	13
1730	15	15	15	15	15	16	16	16	16	17
1740	17	17	17	17	17	19	19	19	19	19
1750	19	19	19	19	19	19	19	19	19	19
1760	19	19	19	19	19	19	20	20	20	20
1770	21	21	21	21	21	21	21	22	22	22
1780	22	22	22	22	22	22	22	22	22	22
1790	22	22	22	22	22	22	22	22	22	22
1800	22	22	22	22	22	23	23	23	23	25
1810	25	25	25	25	26	26	26	26	26	26
1820	26	26	26	26	26	27	27	27	27	27
1830	29	30	30	30	30	30	31	31	31	31
1840	31	31	32	32	32	32	33	33	33	33
1850	33	33	32	32	32	32	32	32	32	33
1860	33	33	33	33	33	33	33	33	33	33
1870	33	33	33	34	34	34	34	34	34	34
1880	35	35	35	36	36	36	37	37	37	37
1890	37	37	37	37	37	37	37	37	37	37
1900	37	36	36	36	36	36	36	36	36	36
1910	36	36	36	36	36	36	36	36	36	36
1920	36	36	36	36	36	36	36	36	36	36
1930	36	36	36	36	36	36	36	36	36	36
1940	36	36	36	36	36	36	36	36	36	36
1950	36	36	36	36	36	36	36	36	36	36
1960	36	36	36	36	36	36	36	36	36	36
1970	36	36	36	36	36	36	36	36	36	36
1980	36	36	36	36	36	36	36	36	36	36
1990	28									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: ENC.RWL
51 SERIES IN FILE, 13 NOT USED
CORE MASK: 12345678901234567890123456789012345678901234567890123456789012345678901
00000120012301121201210212312012123102121021212121212
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ. RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
13 SPECIAL (NON-DEFAULT) CURVE FITS
38 CORES, 18 TREES IN FINAL CHRONOLOGY

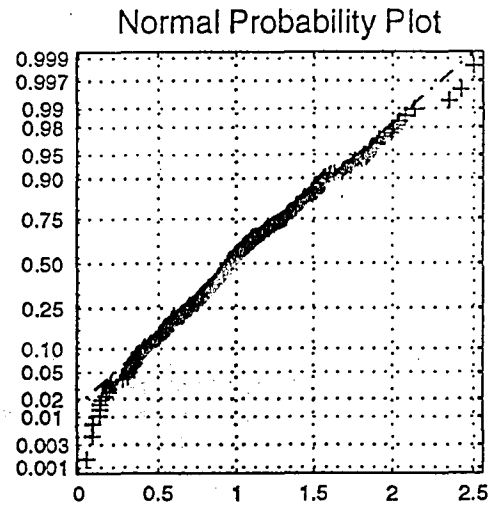
REMARKS

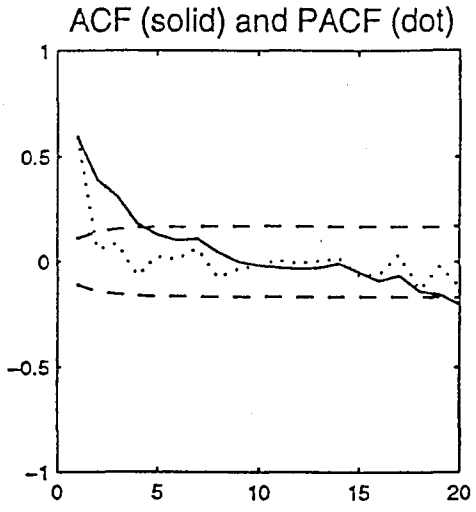
South side of Slim Buttes in Custer National Forest, northwestern South Dakota, 29 km southeast of Buffalo, South Dakota. Chronology species -- ponderosa pine. Most samples are from the upper slopes of draws leading down the northeastern side of Eagle Nest Canyon. Fire scars and heart rot are common. The aspect is mostly west or southwest. Some cutting is evident along the ridges. The oldest samples are from grassy hillsides with 30-40 degree slopes and variable aspects. This site is probably within a few hundred meters of the "Slim Butte" site collected in September 1980 by T. Harlan and D. Meko, and used in a published precipitation reconstruction (J. Clim. and Appl. Met., 22(1), 1983). The earlier chronology, deck 545640 in the Arizona Tree-Ring Lab. database, covers 1624-1979.

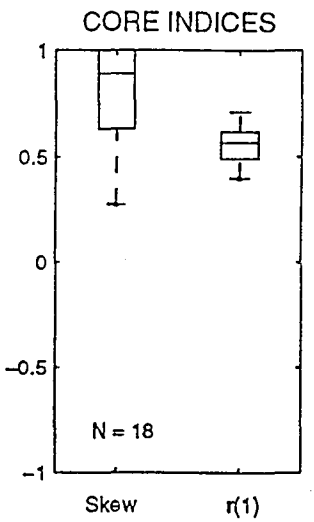
EAGLE NEST CANYON

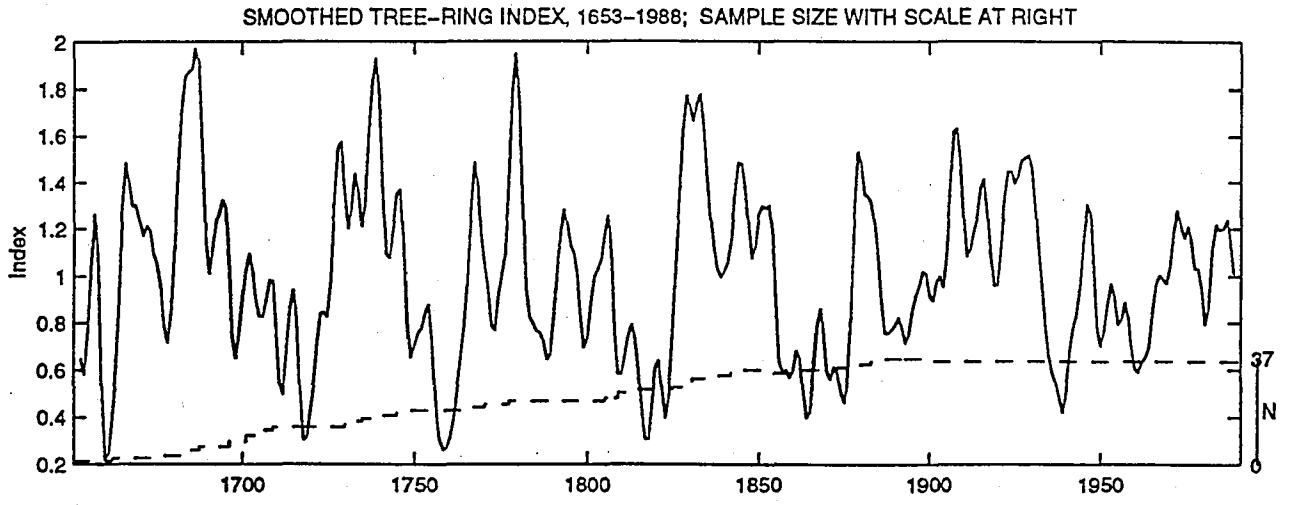
Climate Stations and Distances to Tree-Ring Site:

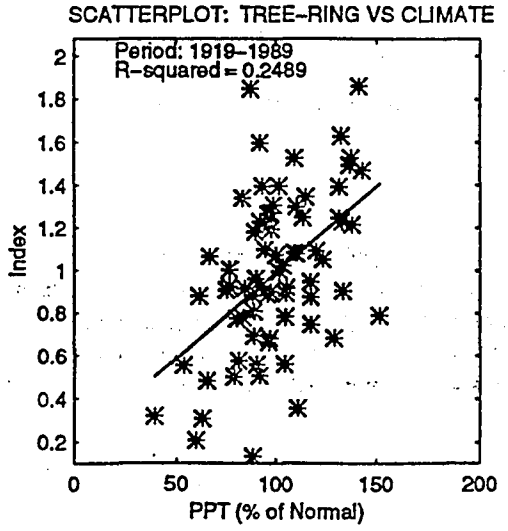
	State	ID	Distance (km)
HETTINGER	ND	32074178	80
COLONY	WY	48061905	96

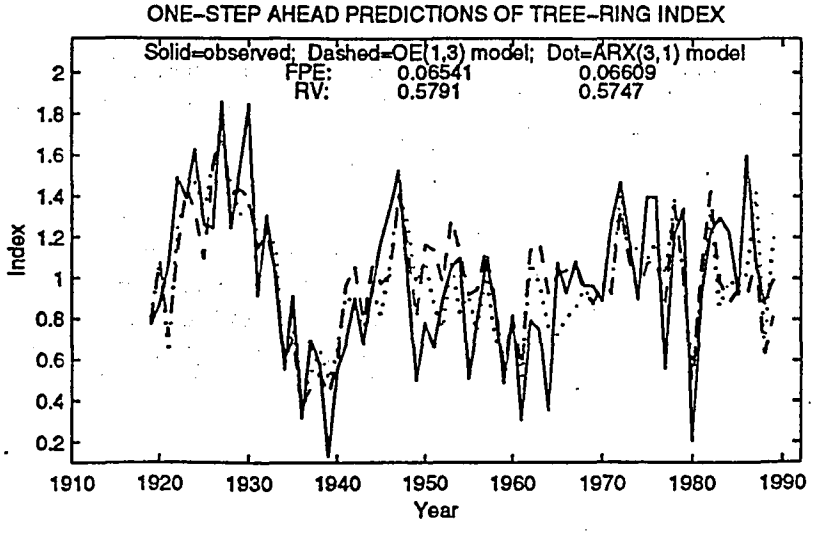












7 GCE Grace Coolidge Oak SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1767								199	154	106
1770	89	114	97	112	83	109	92	106	95	116
1780	125	99	76	111	104	70	64	75	110	99
1790	91	53	84	82	123	157	112	89	92	94
1800	57	51	78	112	90	117	125	76	72	67
1810	84	105	86	121	105	91	122	99	81	99
1820	89	96	64	63	58	77	116	150	139	115
1830	144	128	161	136	129	125	110	118	86	100
1840	101	122	100	86	127	126	108	80	74	79
1850	112	127	124	145	142	103	82	88	88	79
1860	84	103	106	84	91	67	98	98	78	94
1870	78	72	71	98	78	68	61	71	103	120
1880	84	79	102	96	96	114	89	109	116	95
1890	104	105	121	91	74	83	61	66	68	86
1900	82	93	122	105	117	116	92	141	124	132
1910	72	52	122	96	86	79	107	109	95	94
1920	87	85	140	162	143	168	150	139	143	154
1930	126	83	138	130	82	128	76	78	71	54
1940	53	84	115	108	81	96	85	86	67	93
1950	98	91	84	99	80	75	80	123	138	102
1960	81	74	102	98	113	116	78	97	94	90
1970	95	121	119	99	79	88	74	78	114	112
1980	91	110	120	104	116	82	132	110	96	97
1990	123	124								

Number of samples

	0	1	2	3	4	5	6	7	8	9
								1	2	2
	2	2	2	2	2	3	3	3	3	3
	3	3	3	3	3	3	3	3	3	4
	4	4	4	4	4	4	4	4	4	4
	4	5	6	6	6	6	7	7	7	7
	7	7	8	8	8	8	8	9	11	11
	11	11	12	12	12	12	12	12	12	13
	13	13	13	13	13	13	13	13	13	13
	13	13	13	13	13	13	13	13	13	13
	13	13	13	14	14	14	14	14	14	14
	14	14	14	14	14	14	14	14	14	14
	16	16	16	17	17	17	17	16	16	16
	16	16	16	18	18	18	18	20	20	21
	22	22	24	24	25	25	25	25	25	25
	27	27	27	28	28	28	28	28	30	30
	30	30	30	30	30	30	30	32	32	32
	33	33	33	33	33	30	30	30	30	30
	30	30	30	30	30	30	30	30	30	30
	30	30	30	30	30	30	30	30	30	30
	27	27	27	27	27	27	26	26	26	26
	26	26	26	26	26	26	26	26	26	26
	26	26	26	26	26	26	26	26	26	26
	26	26	26	26	26	26	26	26	26	26
	25	2								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: GCE.RWL
41 SERIES IN FILE, 7 NOT USED
CORE MASK: 12345678901234567890123456789012345678901
10101201234121212312123123123121212011212000
DEFAULT FIRST CURVE FIT: NEG. EXPONENTIAL OR STRAIGHT LINE WITH NEG. SLOPE
DEFAULT SECOND CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
21 SPECIAL (NON-DEFAULT) CURVE FITS
34 CORES, 16 TREES IN FINAL CHRONOLOGY

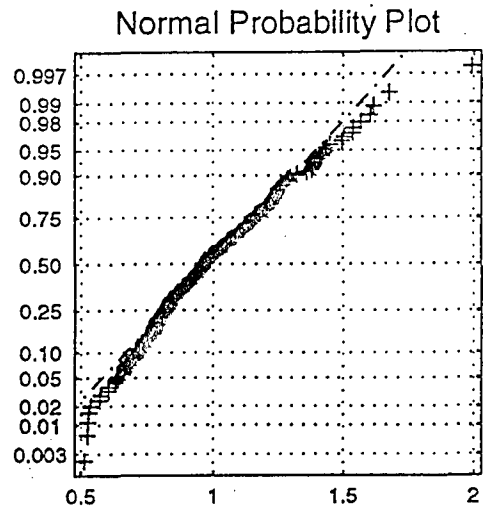
REMARKS

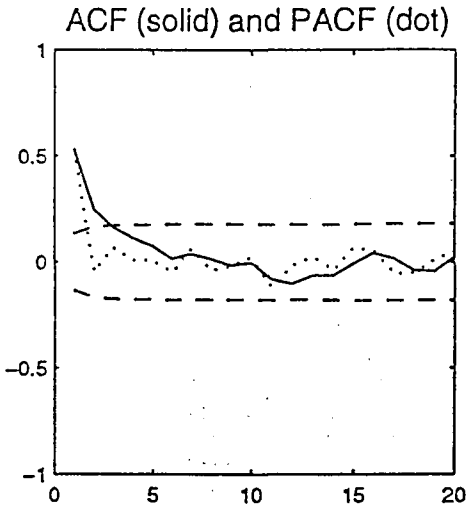
Grace Coolidge Creek State Park in the southern Black Hills of southwestern South Dakota, 19 km east of Custer, South Dakota. Chronology species -- bur oak. Samples are from grassy, gently sloping hillsides and flats. The aspect is mostly south or west. The oldest sampled tree (inner ring, 1767) is growing in the open, on a 10-degree slope with a dense grass understory. Centers are rotten on most samples. The hillside with trees 16-22 was swept by an extremely hot fire in 1988. Ponderosa pine samples were also collected and developed into a chronology at this site -- chronology code GCP.

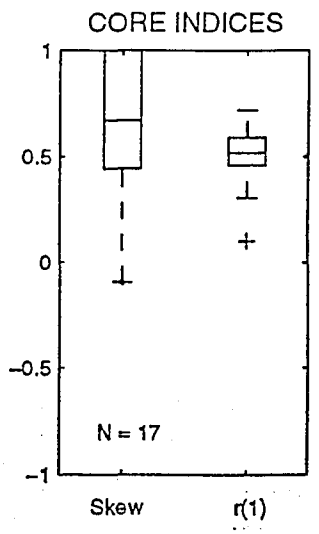
GRACE COOLIDGE OAK

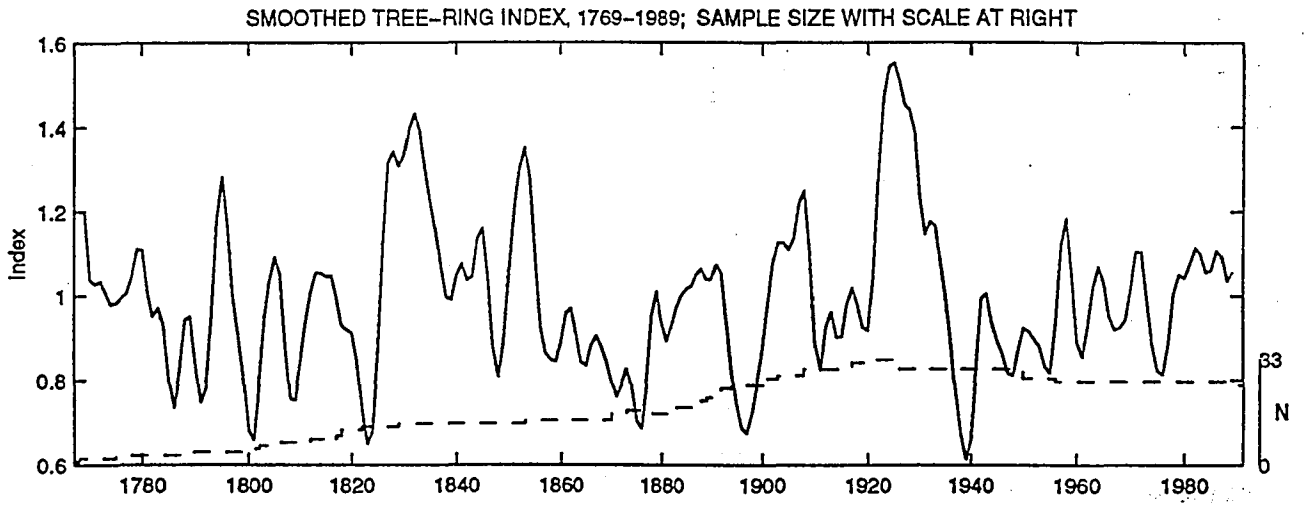
Climate Stations and Distances to Tree-Ring Site:

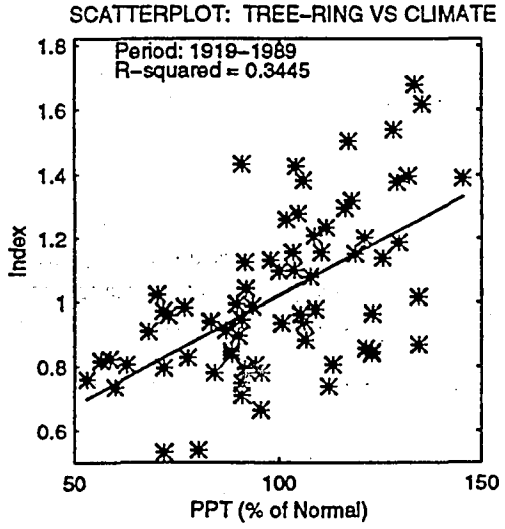
	State	ID	Distance (km)
RAPID CITY	SD	39056947	36
HOT SPRINGS	SD	39044007	38
NEWCASTLE	WY	48076660	70

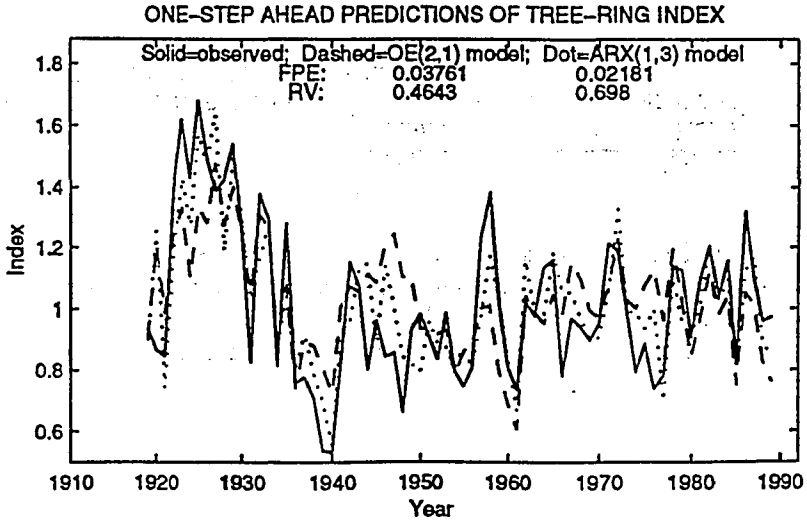












8 GCE Grace Coolidge Pine SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1703				123	71	84	50	62	73	107
1710	26	61	52	87	87	116	139	44	37	42
1720	74	43	118	99	113	146	145	185	179	192
1730	143	107	96	156	85	75	62	199	134	155
1740	162	49	89	79	82	93	55	63	62	51
1750	89	82	111	129	128	116	32	12	13	13
1760	36	65	90	110	131	91	124	175	148	136
1770	140	162	101	106	114	130	103	144	157	105
1780	146	108	95	101	98	50	74	84	67	72
1790	91	72	112	135	146	135	117	101	85	80
1800	93	105	105	115	112	117	167	125	69	48
1810	70	79	95	140	122	97	148	79	93	86
1820	114	129	67	33	29	58	71	104	118	94
1830	139	112	120	157	122	100	151	123	122	112
1840	141	133	154	127	197	135	125	76	57	100
1850	107	143	117	152	119	79	56	56	92	62
1860	56	73	70	46	54	21	48	70	59	107
1870	63	81	68	90	66	51	40	45	84	89
1880	49	79	116	105	102	157	130	128	160	156
1890	117	127	126	97	84	80	65	70	78	94
1900	95	86	132	136	133	159	126	199	179	147
1910	105	25	135	91	101	179	154	89	159	88
1920	51	80	102	112	93	138	116	112	112	109
1930	95	75	143	109	44	74	45	72	87	29
1940	39	77	94	84	103	149	130	150	152	111
1950	50	72	103	125	94	106	96	127	132	91
1960	74	81	134	122	67	125	66	94	105	89
1970	92	130	134	93	69	132	157	76	82	78
1980	66	105	114	110	117	29	115	109	50	72
1990	135									

Number of samples

	0	1	2	3	4	5	6	7	8	9
				1	1	1	1	1	1	1
	2	2	2	2	3	3	3	3	3	3
	3	3	3	3	3	3	3	3	3	3
	3	3	3	3	3	3	3	3	3	3
	3	3	3	3	3	4	4	4	4	4
	4	4	4	4	4	4	4	4	4	4
	4	4	4	4	4	4	4	4	4	4
	4	4	4	4	5	5	5	5	6	6
	6	6	6	6	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	8	8	8	8	8	8	8	8	8
	8	8	8	8	9	9	9	9	9	9
	9	9	9	9	9	9	9	10	10	10
	13	13	13	13	13	13	13	13	13	14
	14	15	16	16	16	16	16	16	16	16
	16	16	16	16	16	16	16	16	16	16
	16	16	16	16	16	16	16	16	16	16
	16	16	16	16	16	16	16	16	16	17
	18	18	18	18	18	18	18	18	18	18
	19	19	19	19	19	19	19	19	19	19
	19	16	16	16	16	16	17	17	17	18
	18	18	18	18	18	18	18	18	18	19
	20	20	21	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	22	22	22
	22	22	22	22	22	22	22	20	20	20
	17									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: GCP.RWL
25 SERIES IN FILE, 0 NOT USED
CORE MASK: 1234567890123456789012345
1231212112121231212121212
DEFAULT FIRST CURVE FIT: NEG. EXPONENTIAL OR STRAIGHT LINE WITH NEG. SLOPE
DEFAULT SECOND CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
7 SPECIAL (NON-DEFAULT) CURVE FITS
25 CORES, 12 TREES IN FINAL CHRONOLOGY

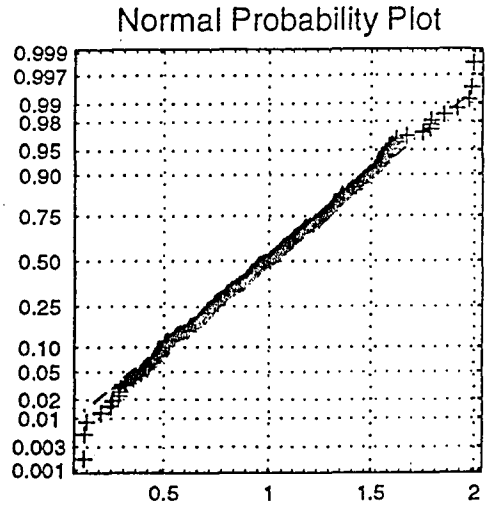
REMARKS

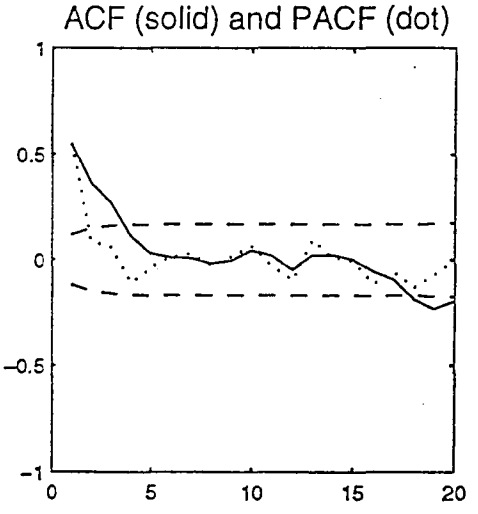
Grace Coolidge East State Park in the southern Black Hills of southwestern South Dakota, 19 km east of Custer, South Dakota. Chronology species -- ponderosa pine. The aspect is mostly south or west. The oldest sampled tree (inner ring, 1703) is flat-topped, and growing in rocky soil on a 30-degree slope. The hillside with trees 16-22 was swept by an extremely hot fire in 1988. Bur oak was also collected at this site -- chronology code GCE.

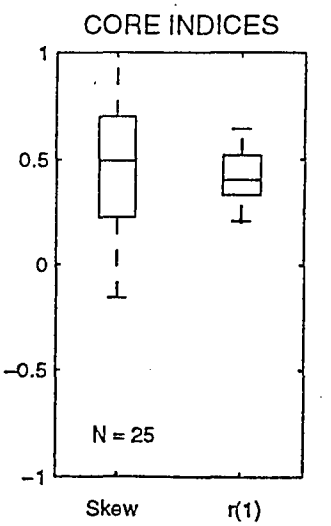
GRACE COOLIDGE PINE

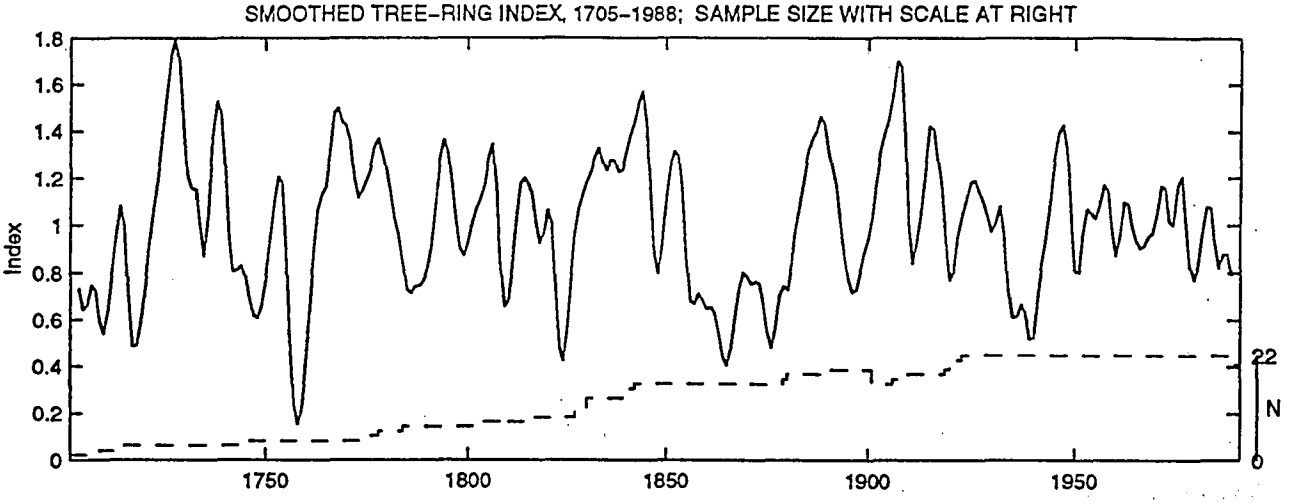
Climate Stations and Distances to Tree-Ring Site:

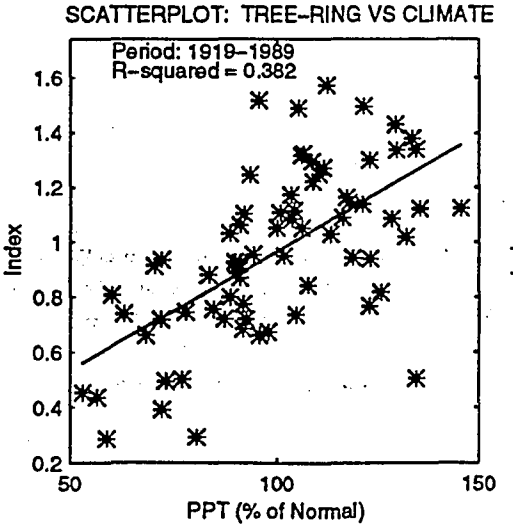
	State	ID	Distance (km)
RAPID CITY	SD	39056947	36
HOT SPRINGS	SD	39044007	38
NEWCASTLE	WY	48076660	70

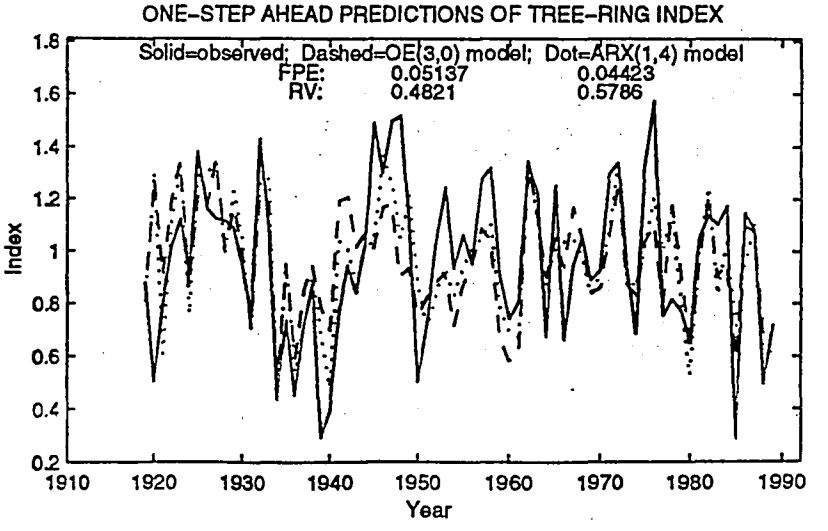












9 HNK Hankins Group SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1875						49	59	83	117	113
1880	117	97	113	106	95	126	78	104	114	109
1890	130	140	132	103	102	99	83	66	77	86
1900	88	88	95	113	104	95	70	103	106	111
1910	87	85	98	85	80	63	94	97	101	99
1920	115	90	111	115	125	130	127	132	121	115
1930	108	89	153	126	94	101	77	66	71	63
1940	71	84	106	97	82	98	84	102	96	109
1950	109	86	94	130	123	121	109	141	89	98
1960	87	72	84	91	112	119	91	96	102	109
1970	107	110	123	101	84	85	98	104	123	112
1980	81	96	122	95	107	74	127	87	85	107
1990	95									

Number of samples

	0	1	2	3	4	5	6	7	8	9
						2	2	3	3	3
	4	4	4	5	5	5	6	6	6	6
	6	6	6	6	6	6	6	6	6	6
	9	9	9	9	9	9	9	9	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	9	9	9	9	9
	9	9	9	9	9	9	9	9	9	9
	9									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: HNK.RWL
12 SERIES IN FILE, 2 NOT USED
CORE MASK: 123456789012
120111011111
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT WAVELENGTH 70 YR
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
4 SPECIAL (NON-DEFAULT) CURVE FITS
10 CORES, 9 TREES IN FINAL CHRONOLOGY

REMARKS

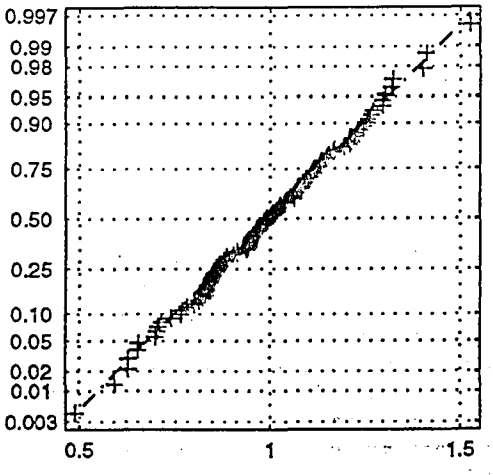
Private land in the northern Black Hills of southwestern South Dakota, 5 km northeast of Deadwood, South Dakota. Chronology species -- bur oak. This chronology was formed by combining cores from four sites, each with only one or a few sampled trees. The site codes are HNK, ORC, SNY and WIL. HNK trees are from a dense bur oak stand on a 20-degree slope in an area logged about 8 years ago. ORC trees are growing in a flat, open site, and show extensive leaf damage from insects. SNY trees are growing in a swale in an open meadow. WIL trees are from a pasture, in a hillside swale, with dead or dying trees. Heart rot is common to trees at the sites.

HANKINS GROUP

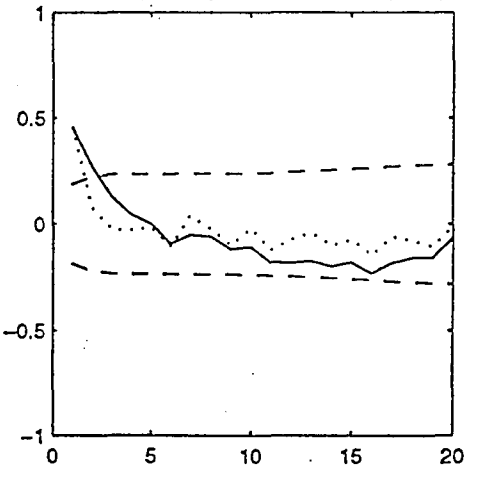
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
RAPID CITY	SD	39056947	44
NEWCASTLE	WY	48076660	69
COLONY	WY	48061905	78

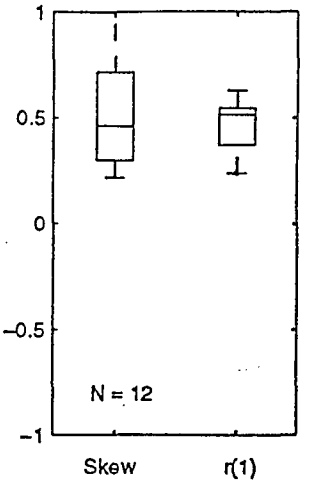
Normal Probability Plot



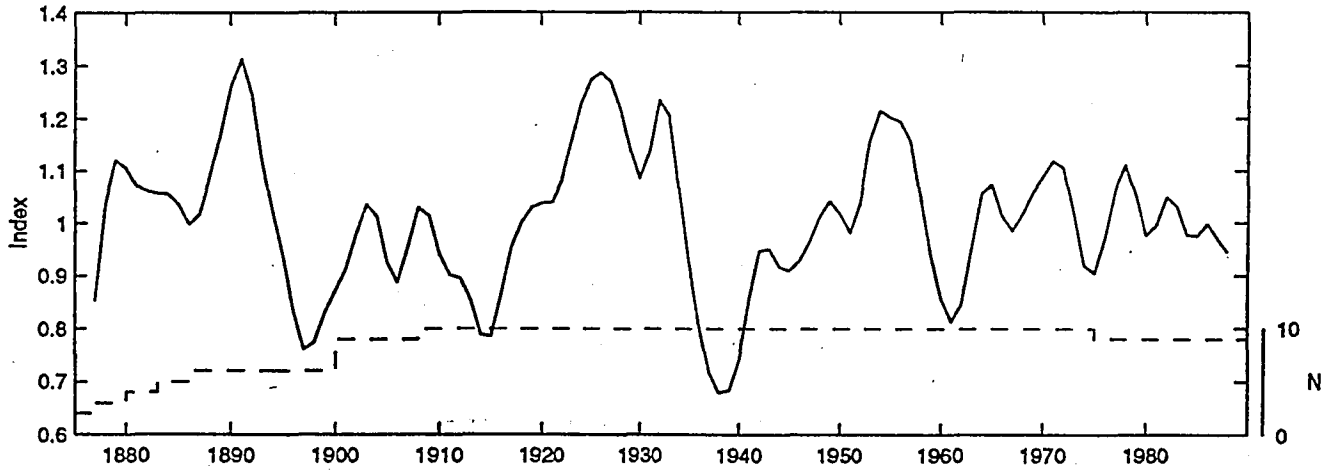
ACF (solid) and PACF (dot)



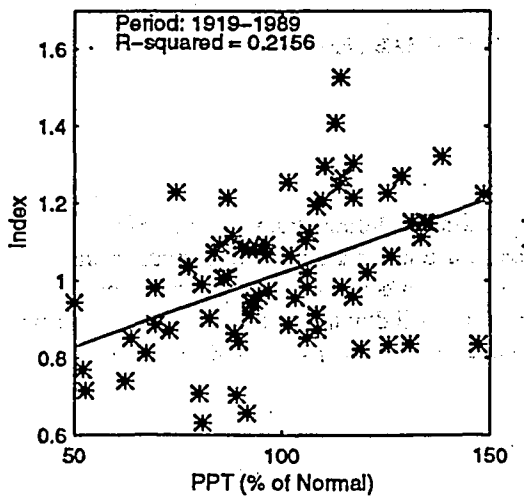
CORE INDICES



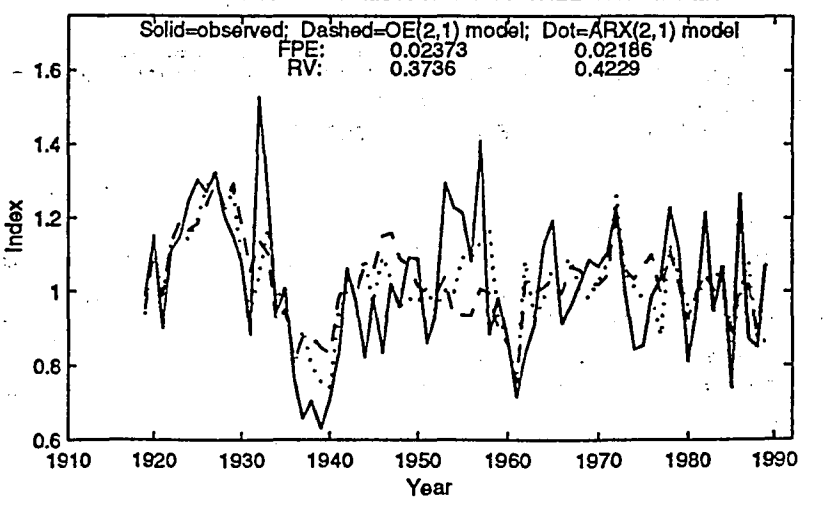
SMOOTHED TREE-RING INDEX, 1877-1988; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



10 BLR Blair SD

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1753				35	74	49	132	75	37	33				1	1	1	1	1	1	1
1760	37	82	90	95	103	132	123	112	115	94	2	2	2	2	2	2	2	2	2	3
1770	85	145	139	146	119	104	99	127	125	107	3	3	3	3	3	3	3	3	3	3
1780	123	128	89	94	122	97	66	49	67	77	3	3	3	3	3	4	4	4	4	4
1790	84	62	85	69	111	124	107	131	118	119	4	4	4	4	4	4	4	4	4	4
1800	51	91	95	89	84	142	149	106	114	91	4	4	4	4	4	4	4	4	4	4
1810	126	134	109	127	104	113	113	119	93	96	4	4	4	4	4	4	4	4	4	4
1820	86	89	69	76	90	88	149	124	79	95	5	5	5	5	5	5	5	5	5	5
1830	110	88	115	117	113	141	113	94	69	79	4	4	4	4	4	4	4	4	4	4
1840	96	147	44	70	107	79	93	115	93	95	4	4	4	4	4	4	4	4	4	4
1850	80	93	94	100	100	66	96	115	125	150	4	4	4	4	4	4	6	6	6	6
1860	86	106	109	96	99	80	104	82	89	97	6	6	6	6	6	6	6	6	7	7
1870	77	75	81	95	83	71	70	75	88	106	7	7	7	7	7	7	7	7	8	8
1880	96	77	91	94	107	110	89	105	111	126	8	8	8	8	8	8	8	8	8	8
1890	102	158	141	121	140	131	105	79	91	96	8	8	8	9	9	9	9	9	9	9
1900	75	95	141	146	143	132	77	104	98	116	9	9	9	9	9	9	9	9	9	9
1910	77	75	98	102	79	64	92	99	89	101	9	9	9	9	9	9	9	9	9	9
1920	87	81	123	116	104	114	128	127	123	105	9	9	9	9	9	9	9	9	9	9
1930	92	64	124	124	114	102	96	87	75	72	9	9	9	9	9	9	9	9	9	9
1940	81	109	144	90	94	113	83	87	105	131	9	9	9	9	9	9	9	9	9	9
1950	129	104	101	120	108	102	110	137	109	96	9	9	9	9	9	9	9	9	9	9
1960	74	64	88	81	113	103	100	70	97	110	9	9	9	9	9	9	9	9	9	9
1970	100	109	139	101	79	81	103	89	112	97	9	9	9	9	9	9	9	9	9	9
1980	67	96	125	101	106	99	128	106	89	103	9	9	9	9	9	9	9	9	9	9
1990	108										9									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: BLR.RWL
13 SERIES IN FILE, 3 NOT USED
CORE MASK: 1234567890123
1212112000111
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
3 SPECIAL (NON-DEFAULT) CURVE FITS
10 CORES, 7 TREES IN FINAL CHRONOLOGY

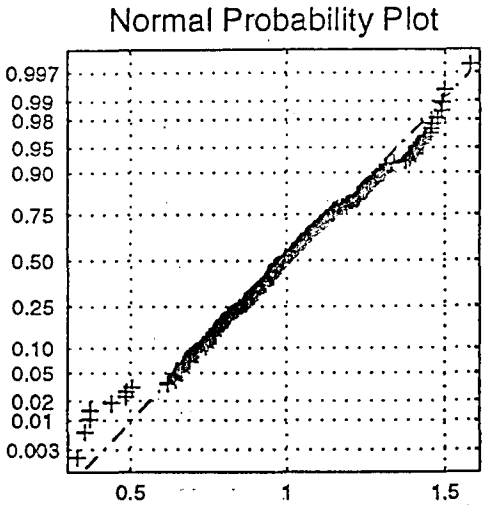
REMARKS

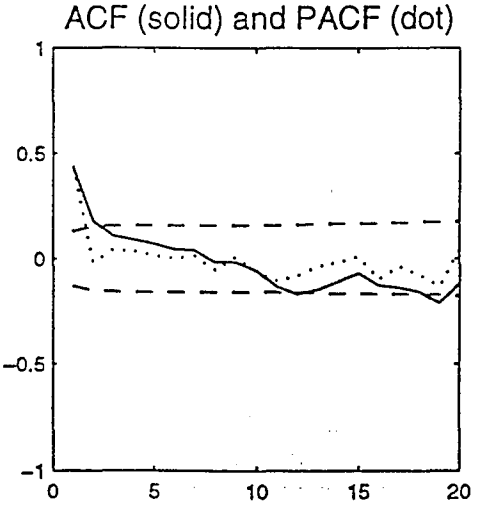
Private land in the northern Black Hills of South Dakota, 8 km southeast of Sturgis, South Dakota. Chronology species -- bur oak. The site contains a fairly dense cover of mature bur oak, ash and box elder along drainages, and is overgrazed down to the mineral soil -- no understory. An old photo (1890) shows a heavy oak component along streams and no ponderosa pine on the hill to the north; pines grow there today. All drainages sampled lead to Pleasant Valley Creek. The oldest sampled tree has a ring count back to 1712, but only the portion from 1878 on was used in the chronology because of uncertain crossdating.

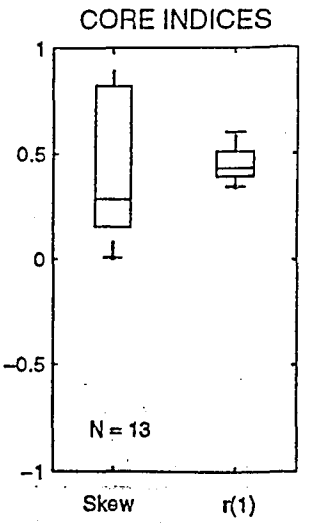
BLAIR

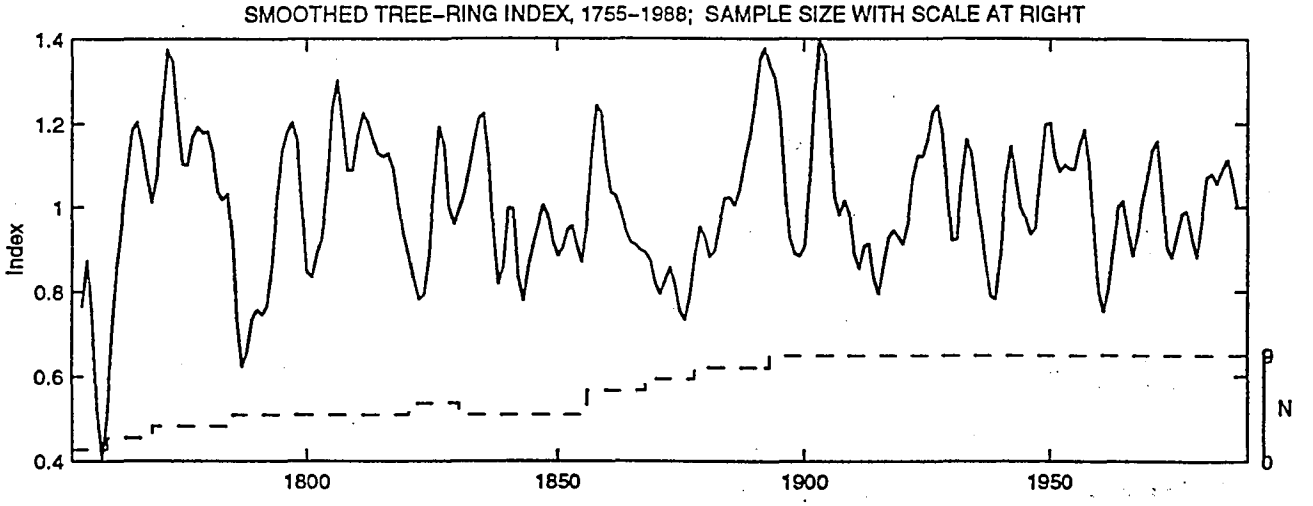
Climate Stations and Distances to Tree-Ring Site:

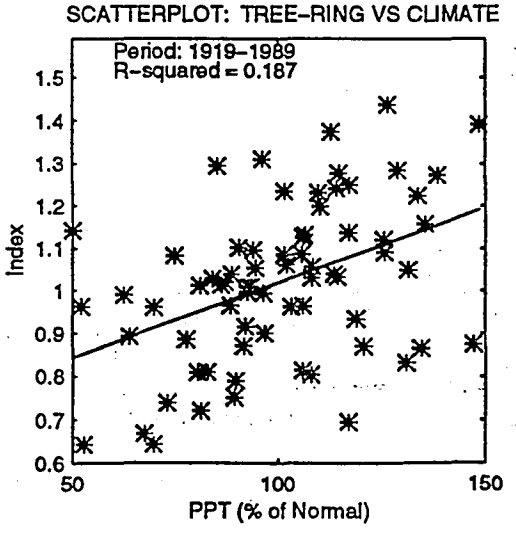
	State	ID	Distance (km)
RAPID CITY	SD	39056947	32
NEWCASTLE	WY	48076660	83
COLONY	WY	48061905	89

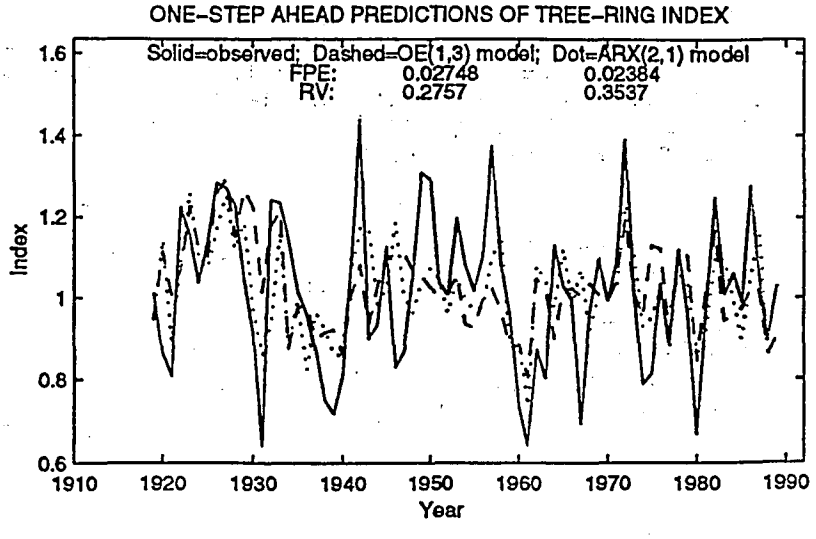












11 BCV Burning Coal Vein ND

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1600	106	194	156	130	151	67	132	157	127	167
1610	140	171	172	174	97	194	148	174	124	124
1620	84	110	138	79	51	89	99	81	88	84
1630	54	65	47	64	62	61	61	30	59	70
1640	68	81	99	129	125	82	68	98	46	71
1650	60	88	65	56	72	66	97	66	105	86
1660	75	92	73	115	103	91	125	89	54	109
1670	137	107	108	122	102	99	135	115	117	74
1680	113	106	113	157	148	131	135	124	117	101
1690	63	92	104	88	112	150	102	102	99	126
1700	105	88	116	94	82	80	50	115	65	102
1710	123	67	88	116	92	105	117	55	58	129
1720	90	61	107	99	72	90	137	114	100	122
1730	83	93	90	112	48	61	51	106	126	114
1740	134	46	69	63	94	48	69	81	116	73
1750	97	103	127	92	158	98	38	35	51	39
1760	61	85	89	114	110	146	166	151	145	113
1770	109	142	97	136	134	116	104	125	132	85
1780	101	95	105	124	107	69	95	104	91	86
1790	98	72	99	109	80	93	98	87	75	109
1800	69	104	100	122	96	85	96	77	55	58
1810	77	101	87	108	110	84	144	78	80	94
1820	99	112	87	61	75	114	107	114	137	150
1830	164	122	116	148	145	109	121	122	94	107
1840	136	125	133	125	146	103	114	108	47	123
1850	79	92	81	128	123	97	56	93	128	100
1860	70	75	111	47	71	73	74	77	85	104
1870	66	76	54	92	92	98	59	79	107	102
1880	41	70	116	115	102	129	139	140	174	148
1890	126	142	121	95	118	76	42	75	82	101
1900	91	91	112	120	136	131	132	163	146	151
1910	82	23	107	112	110	128	105	81	108	79
1920	77	87	103	99	76	90	68	92	75	85
1930	81	65	108	97	30	77	77	93	105	34
1940	64	108	118	126	130	142	132	144	81	108
1950	85	73	79	94	62	111	108	104	107	96
1960	80	55	97	130	120	149	94	108	109	126
1970	114	111	136	134	80	108	83	54	88	85
1980	69	109	127	137	170	22	144	108	64	87
1990	112	109								

Number of samples

Date	0	1	2	3	4	5	6	7	8	9
1600	1	1	1	1	1	1	1	1	1	1
1610	2	2	2	2	2	2	2	2	2	2
1620	2	2	2	2	2	2	2	2	2	2
1630	2	2	2	2	2	2	2	2	2	2
1640	3	3	3	3	3	3	3	3	3	3
1650	3	3	3	3	3	3	3	3	3	3
1660	3	3	3	3	3	3	3	3	3	5
1670	6	7	7	7	7	8	9	9	9	9
1680	9	9	9	9	9	10	10	10	10	10
1690	10	10	10	11	11	11	11	11	11	11
1700	11	11	12	13	13	14	14	14	14	14
1710	14	14	14	14	14	14	14	14	14	14
1720	14	14	14	14	14	14	14	14	14	14
1730	14	14	14	14	14	14	14	14	14	14
1740	14	14	14	14	14	14	14	14	14	14
1750	15	16	16	16	16	16	16	16	16	16
1760	16	16	16	16	16	17	17	19	20	20
1770	22	22	22	22	22	23	26	26	27	27
1780	27	27	27	27	27	28	28	28	28	28
1790	28	28	29	29	29	29	29	29	29	29
1800	29	29	29	29	29	29	29	29	29	29
1810	29	29	29	29	29	29	29	29	29	29
1820	29	29	29	29	29	29	29	29	29	29
1830	31	31	31	31	31	31	31	31	31	31
1840	31	31	31	31	31	31	31	31	31	31
1850	31	31	31	31	31	31	31	31	31	31
1860	31	31	31	31	31	31	31	31	31	31
1870	31	31	31	31	31	31	31	31	31	31
1880	31	31	31	31	31	31	31	31	31	31
1890	31	31	31	31	31	31	31	31	31	31
1900	31	31	31	31	31	31	31	31	31	31
1910	31	31	31	31	31	31	31	31	31	31
1920	31	31	31	31	31	31	31	31	31	31
1930	31	31	31	31	31	31	31	31	31	31
1940	31	31	31	31	31	31	31	31	31	31
1950	31	31	31	31	31	31	31	31	31	31
1960	31	31	31	31	31	31	31	31	31	31
1970	31	31	31	31	31	31	31	31	31	31
1980	31	31	31	31	30	30	30	30	30	30
1990	30	27								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: BCV.RWL
51 SERIES IN FILE, 11 NOT USED
CORE MASK: 12345678901234567890123456789012345678901234567890123456789012345678901
00112121200112312101212121210011200123123121212340 0
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 AMPLITUDE FREQ RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
15 SPECIAL (NON-DEFAULT) CURVE FITS
40 CORES, 20 TREES IN FINAL CHRONOLOGY

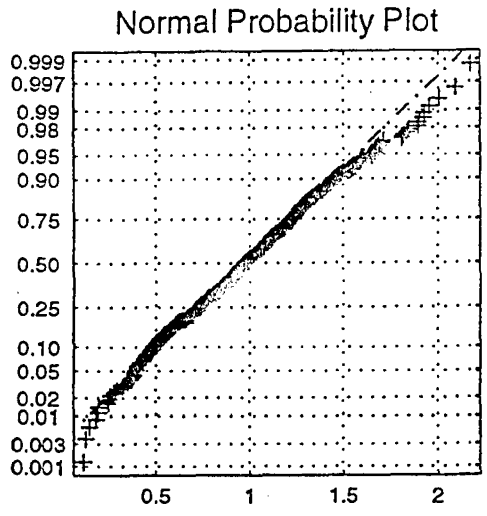
REMARKS

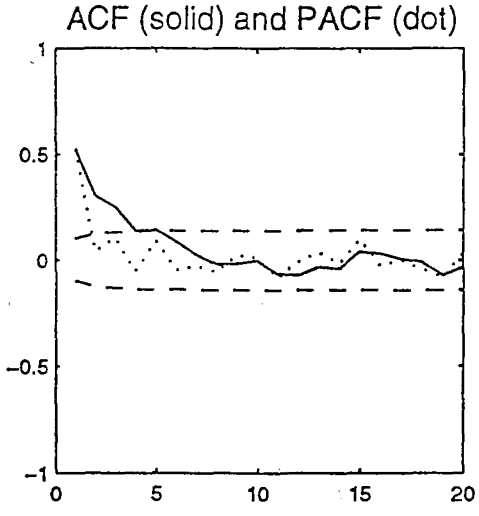
Rocky knolls along the Little Missouri River in southwestern North Dakota, 48 km north of Bowman, North Dakota. Chronology species -- ponderosa pine. The site has a variable aspect, loose shale substrate and thin soil cover. Fire scars are common. The site is detectable from a distance by the flat or slightly rounded tops of old trees rising above the pointed crowns of a much younger population of ponderosa pine. This is a re-collection of a site by the same name collected on September 18, 1980, by T. Harlan and D. Meko, and used in a published precipitation reconstruction (J. Clim. and Appl. Met., 22(1), 1983). The earlier chronology, deck 544640 in the Arizona Tree-Ring Lab. database, covers 1588-1979.

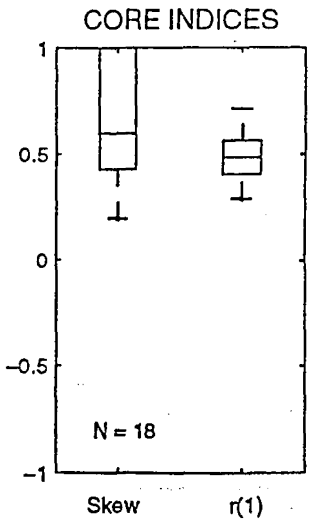
BURNING COAL VEIN

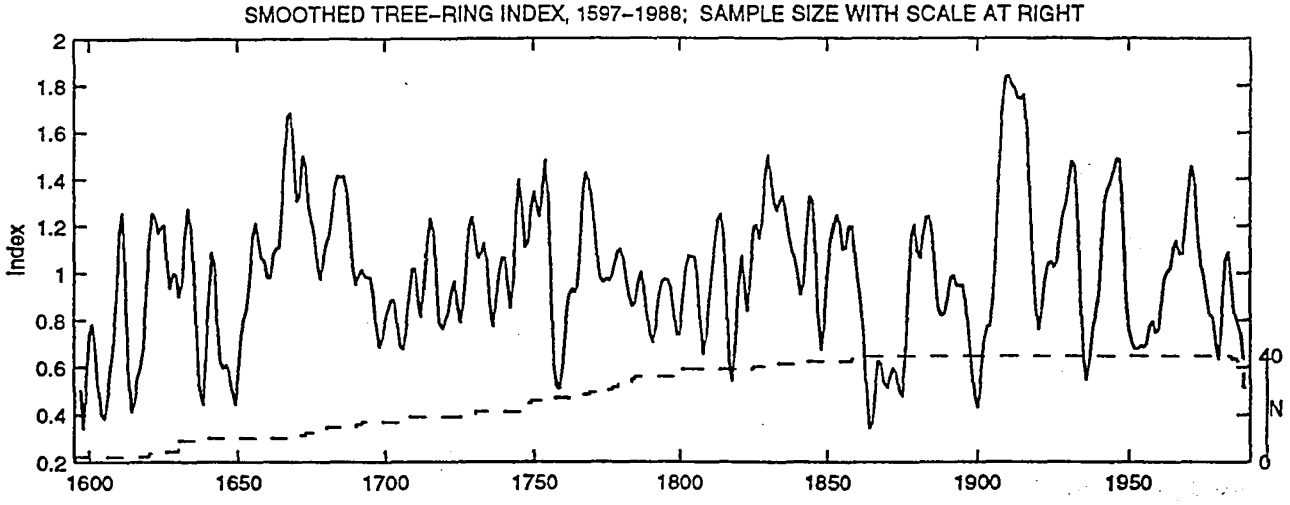
Climate Stations and Distances to Tree-Ring Site:

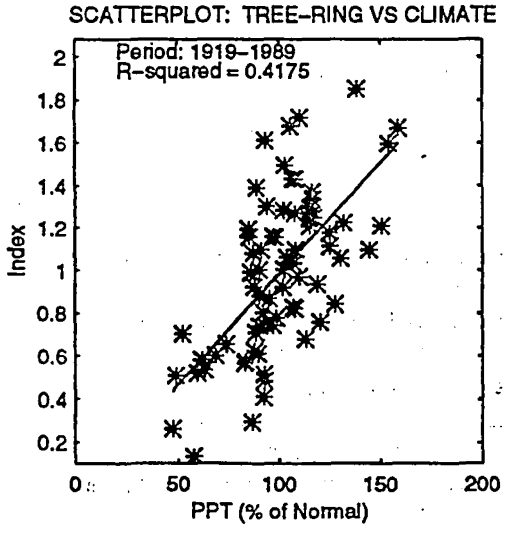
	State	ID	Distance (km)
NEW ENGLAND	ND	32076315	47
DICKINSON EXP ST	ND	32072188	60
PLEVNA	MT	24076501	81

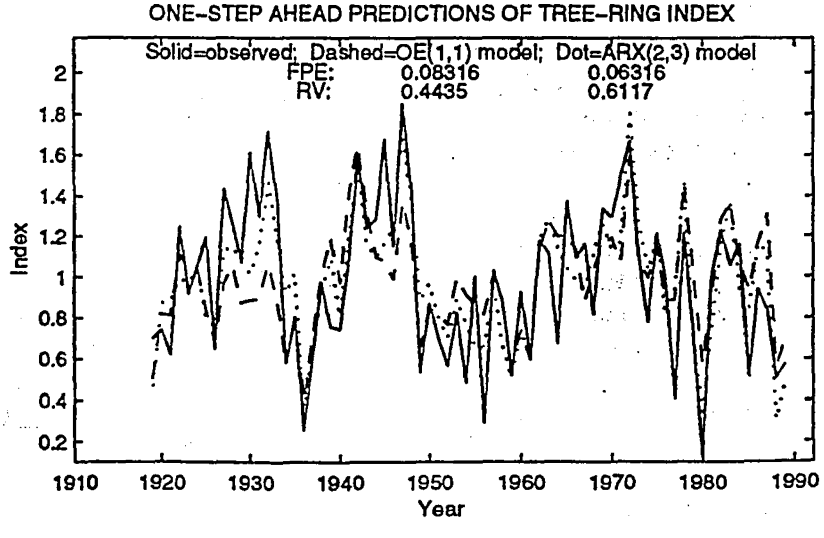












12 PLG Pilger Mountain SD

Date	Tree-Ring Indices										Number of samples									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1646							131	83	64	95							1	1	1	1
1650	121	35	61	88	110	180	134	149	119	125	1	1	1	1	1	1	1	1	2	2
1660	140	90	105	77	82	90	86	58	71	78	2	2	2	2	2	2	2	2	2	2
1670	92	129	121	117	114	156	135	37	39	13	2	2	2	2	2	2	2	2	2	2
1680	36	69	89	76	119	120	126	163	135	108	2	2	2	2	2	2	2	2	2	2
1690	117	140	124	57	41	54	88	95	109	125	2	2	2	2	2	2	2	2	2	2
1700	48	67	123	113	105	106	137	174	80	150	2	3	3	3	3	3	3	3	3	3
1710	94	105	103	124	115	120	129	100	91	132	4	4	4	4	4	4	4	5	5	5
1720	97	68	93	107	88	111	149	143	115	135	5	5	5	5	5	5	5	5	5	5
1730	88	104	94	93	89	91	53	129	96	93	5	5	5	5	5	5	5	5	5	5
1740	145	61	70	66	98	117	109	99	149	112	5	5	5	5	5	5	5	5	5	6
1750	122	114	101	75	86	89	48	34	31	39	6	6	6	6	6	6	6	6	6	6
1760	61	138	111	127	179	155	142	154	107	91	6	6	6	6	6	6	6	6	6	6
1770	134	88	97	124	115	125	99	149	158	123	6	6	6	6	6	6	6	6	6	6
1780	173	125	83	114	90	57	107	88	71	90	6	6	6	6	6	6	6	6	6	6
1790	89	89	148	150	124	130	143	94	61	67	6	6	6	6	6	6	6	6	6	6
1800	63	78	92	96	111	102	123	63	50	53	7	7	7	7	7	7	7	7	7	7
1810	76	76	88	112	118	77	120	65	73	97	7	8	8	8	8	8	8	8	8	8
1820	105	95	77	68	75	104	85	94	105	116	8	8	8	8	8	8	8	8	9	9
1830	142	106	130	108	121	138	152	148	147	130	9	9	9	9	9	9	9	9	9	9
1840	142	143	148	99	125	80	83	52	11	95	9	9	9	9	9	9	9	9	9	9
1850	89	95	95	114	111	73	48	101	96	63	9	9	9	9	9	9	9	9	9	9
1860	71	86	101	58	68	41	80	80	84	103	9	9	9	9	9	9	9	9	9	9
1870	52	61	83	101	61	100	41	16	63	103	9	9	9	9	9	9	9	9	9	9
1880	73	75	130	126	94	126	125	122	136	109	9	9	9	9	9	9	9	9	9	9
1890	118	115	118	61	110	93	83	75	85	98	9	9	9	9	9	9	9	9	9	9
1900	93	105	133	131	146	169	185	140	145	139	9	9	9	9	9	9	9	9	9	9
1910	101	45	102	92	89	167	151	91	162	92	9	8	8	8	8	8	8	8	8	8
1920	71	113	148	107	96	116	114	96	99	92	8	8	8	8	8	8	8	8	8	8
1930	79	88	113	80	33	73	70	90	92	29	8	8	8	8	8	8	8	8	8	8
1940	62	95	92	93	105	158	157	147	161	121	8	8	8	8	8	8	8	8	8	8
1950	106	108	100	102	111	109	100	99	107	62	8	8	8	8	8	8	8	8	8	8
1960	68	49	118	96	56	116	111	114	118	128	8	8	8	8	8	8	8	8	8	8
1970	60	113	118	78	51	125	109	49	98	71	8	8	7	7	7	7	7	7	7	7
1980	67	78	94	86	98	64	130	104	64	65	7	7	7	6	6	6	6	6	6	6
1990	93	93									5	1								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: PLG.RWL
12 SERIES IN FILE, 3 NOT USED
CORE MASK: 123456789012
121200012112
DEFAULT FIRST CURVE FIT: MODIFIED NEG. EXPONENTIAL OR STRAIGHT LINE WITH NEG. SLOPE
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
9 CORES, 5 TREES IN FINAL CHRONOLOGY

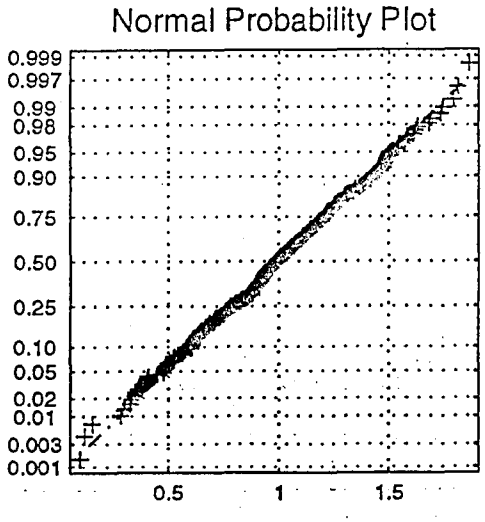
REMARKS

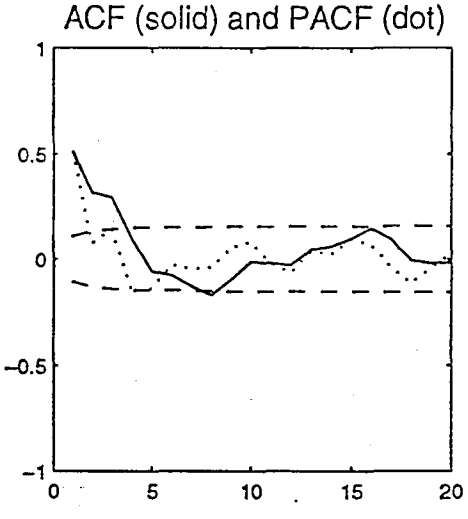
Black Hills National Forest at the southern edge of the Black Hills of southwestern South Dakota, 11 km southeast of Dewey, South Dakota. Chronology species -- ponderosa pine. This chronology was built by merging samples from three separate sites from reconnaissance collections in the southern part of the Black Hills: Pilger Mountain (PLG), Big Tree Draw (BTD), and Horse Thief Lake (HTL). Cores from only PLG and BTD were actually used because the crossdating was uncertain for HTL. The oldest tree used in the chronology (inner ring, 1616) is growing in the open on a 45-degree northwest slope about 6 m above a draw at site BTD, in Custer State Park. A previous collection near site PLG was made by H. Fritts in the early 1960s. The resulting chronology, -- "Pilger Mountain Lookout" site number 146649 in the Arizona Tree-Ring Lab. database -- covers 1520-1964, and is based on 15 trees and 19 cores. A tornado had ripped through and destroyed the old Fritts site about 1990.

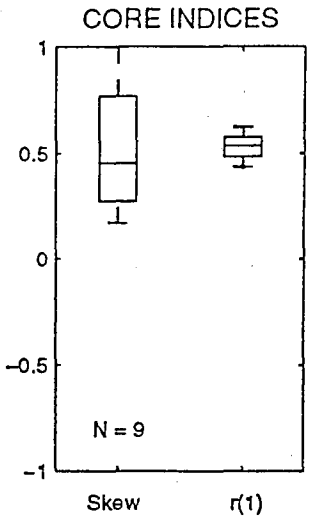
PILGER MOUNTAIN

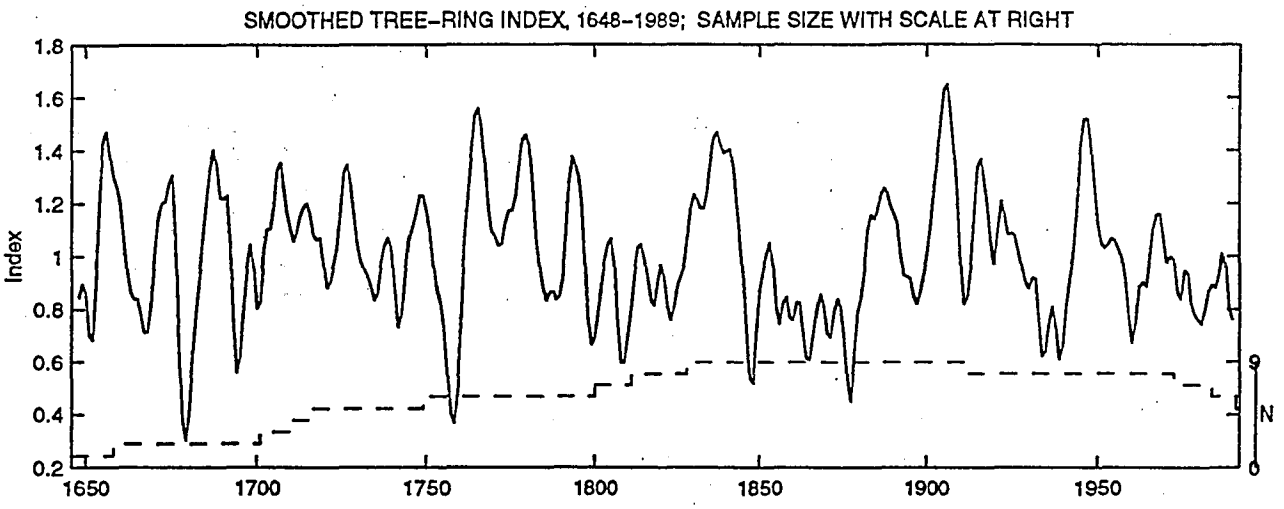
Climate Stations and Distances to Tree-Ring Site:

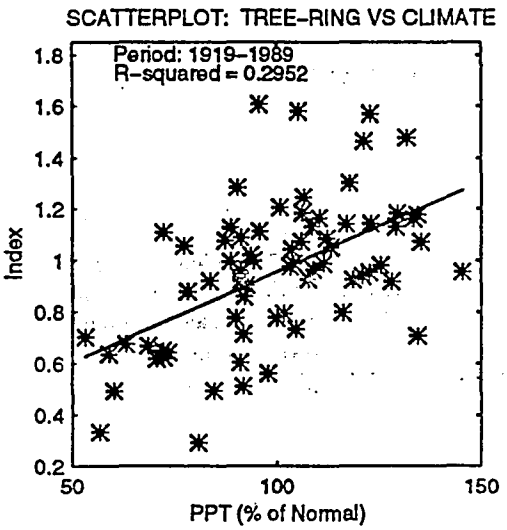
	State	ID	Distance (km)
HOT SPRINGS	SD	39044007	35
NEWCASTLE	WY	48076660	47
RAPID CITY	SD	39056947	82

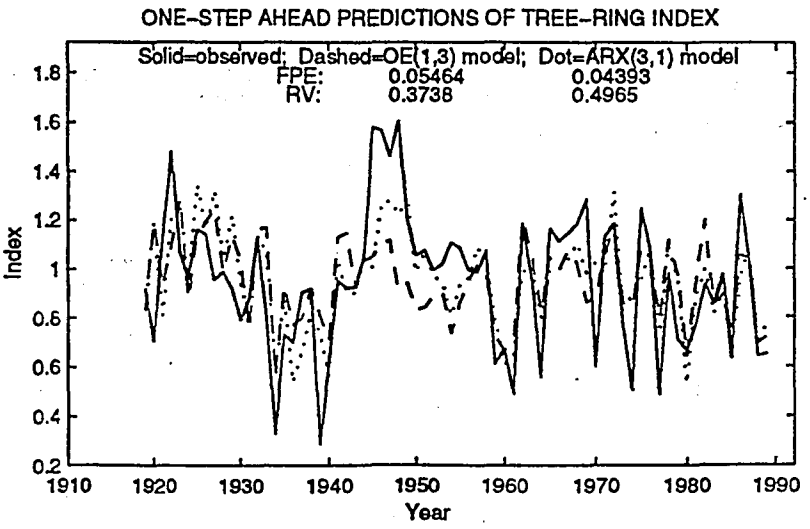












13 TRS Theodore Roosevelt National Park ND

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1630	79	61	104	93	150	113	87	92	72	92
1640	243	266	197	146	58	58	80	108	71	86
1650	80	60	82	82	88	110	127	88	146	160
1660	113	61	118	146	111	81	143	116	118	89
1670	70	55	91	76	94	77	55	47	38	39
1680	46	91	11	144	139	143	137	176	103	86
1690	107	98	100	69	87	82	34	41	42	65
1700	81	87	138	117	73	108	43	104	63	90
1710	184	179	111	122	147	100	120	67	22	100
1720	132	60	79	156	132	112	93	129	190	167
1730	123	90	93	77	81	52	34	109	138	176
1740	176	124	92	75	99	107	105	97	101	105
1750	126	100	85	96	128	112	39	54	72	51
1760	67	74	67	81	112	77	117	160	141	121
1770	118	138	119	104	91	130	115	151	164	160
1780	140	134	93	73	96	78	119	120	110	77
1790	51	45	74	120	65	107	55	105	73	90
1800	51	118	94	126	153	104	99	102	42	84
1810	132	139	117	144	137	100	66	11	26	75
1820	65	85	70	26	85	87	118	95	157	188
1830	173	138	157	115	114	120	97	105	89	77
1840	92	75	72	117	114	88	80	74	79	96
1850	86	160	87	133	141	109	68	97	122	74
1860	90	87	75	32	40	24	99	112	115	110
1870	82	108	88	77	52	64	125	134	178	179
1880	158	137	150	115	89	75	30	54	71	81
1890	65	90	71	70	77	103	93	78	68	96
1900	57	22	79	97	111	90	103	98	120	89
1910	146	136	153	141	126	139	114	131	107	101
1920	84	64	81	94	142	115	32	111	106	118
1930	113	54	98	103	40	85	24	72	107	91
1940	99	132	159	181	161	167	110	139	106	109
1950	84	119	92	83	106	123	42	95	78	80
1960	112	73	117	154	81	112	113	109	101	102
1970	111	126	128	141	122	122	110	53	41	56
1980	34	109	115	107	77	74	95	112	75	113
1990	103	103								

Number of samples

	0	1	2	3	4	5	6	7	8	9
1630	1	1	1	1	1	1	1	1	1	1
1640	1	1	1	1	1	1	1	1	1	1
1650	1	1	1	1	1	1	1	1	1	1
1660	2	2	3	3	3	3	3	3	3	3
1670	3	3	3	3	3	3	3	3	3	3
1680	3	3	3	3	4	6	6	6	6	6
1690	6	6	6	7	7	7	7	7	7	7
1700	7	7	7	7	7	7	7	7	7	7
1710	7	7	7	7	7	7	7	7	7	7
1720	7	7	7	7	7	7	7	7	7	8
1730	8	8	8	8	8	8	8	8	8	8
1740	8	8	9	10	10	10	10	10	12	12
1750	12	12	14	14	14	14	14	14	14	14
1760	15	15	15	15	15	17	17	17	17	17
1770	17	17	17	17	17	17	17	17	17	17
1780	17	18	18	18	18	18	18	19	20	20
1790	20	20	20	21	21	21	23	23	23	23
1800	23	23	24	24	24	24	24	24	24	24
1810	24	24	24	24	24	24	24	24	24	24
1820	24	24	24	24	24	24	26	26	26	26
1830	26	26	26	26	26	26	26	26	26	26
1840	26	26	26	26	26	26	26	26	26	26
1850	26	26	26	26	26	26	26	26	26	26
1860	26	26	26	26	26	26	26	26	26	26
1870	26	26	26	26	26	26	26	26	26	26
1880	26	26	26	26	26	26	26	26	26	27
1890	26	26	27	27	27	28	28	28	28	28
1900	28	27	27	27	27	27	27	27	27	27
1910	27	27	27	27	27	27	27	27	26	26
1920	26	26	26	26	26	26	26	26	26	26
1930	26	26	26	26	26	26	25	25	25	25
1940	25	25	25	25	25	25	25	25	25	25
1950	25	25	25	25	25	25	25	25	25	25
1960	25	25	25	25	25	25	25	25	25	25
1970	25	24	24	24	24	24	23	23	23	23
1980	23	23	23	22	22	22	22	21	21	20
1990	18	1								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: TRS.RWL
42 SERIES IN FILE, 13 NOT USED
CORE MASK: 12345678901234567890123456789012345678901 2
11100000001000112011001212121212121212121212
DEFAULT FIRST CURVE FIT: SLPINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
1 SPECIAL (NON-DEFAULT) CURVE FIT
29 CORES, 18 TREES IN FINAL CHRONOLOGY

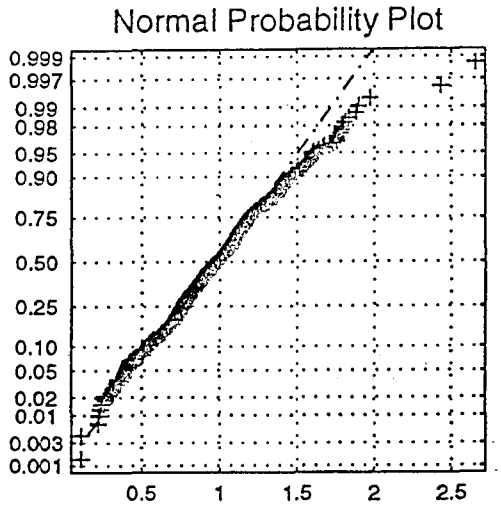
REMARKS

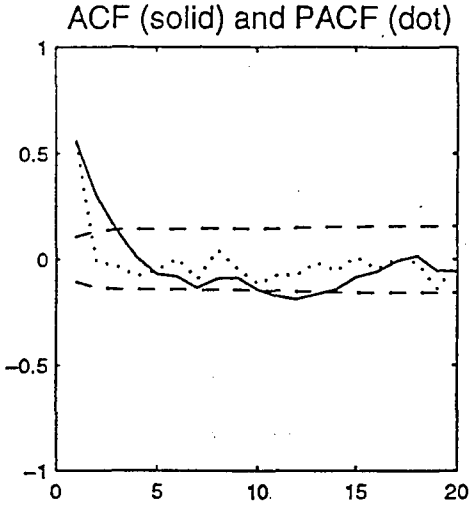
Theodore Roosevelt National Park, southwestern North Dakota, 3 km northeast of Hedora, North Dakota. Chronology species -- Rocky Mountain juniper. Samples are mainly from trees on steeply sloping grassy hillsides in the South Unit of the park. Juniper at the site is also common on the hilltops and in the draws, where it grows alongside green ash. Soil is mainly clay. Heart rot is a serious problem in about half of the sampled trees -- both young and old. The oldest sampled tree (inner ring, estimated 1465) is gnarled in appearance, missing most of its bark, and growing solitary in full sun on a 45-degree north slope.

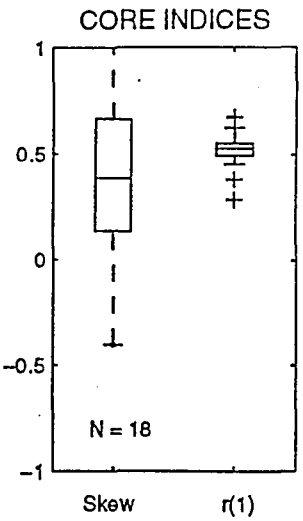
THEODORE ROOSEVELT NTL PARK

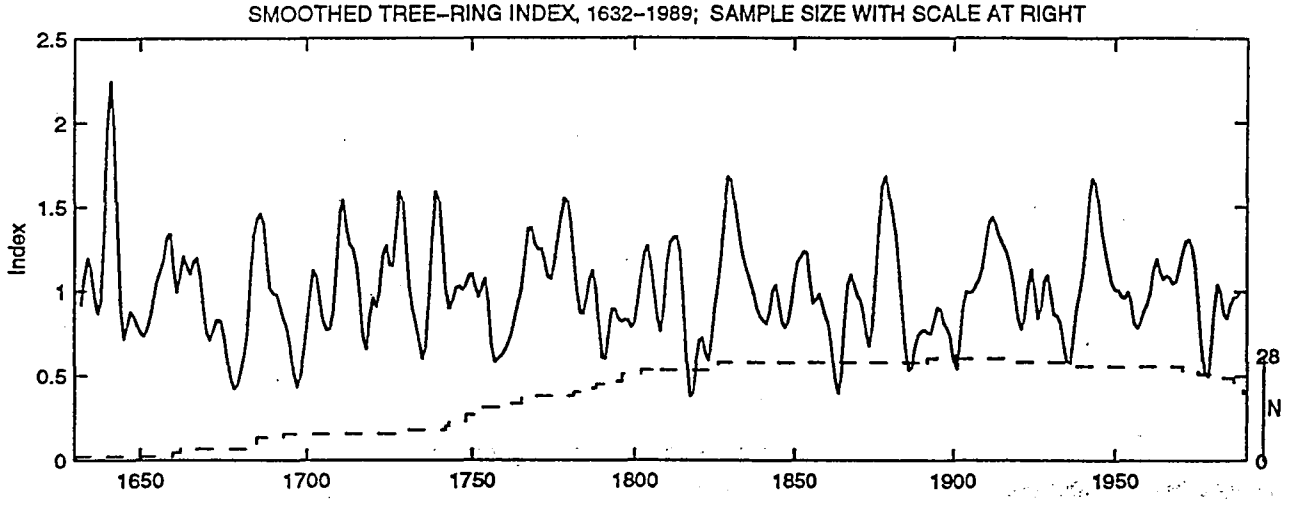
Climate Stations and Distances to Tree-Ring Site:

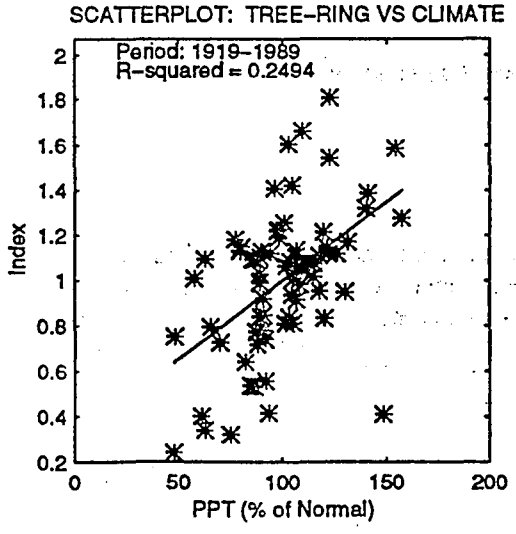
	State	ID	Distance (km)
DICKINSON EXP ST	ND	32072188	52
NEW ENGLAND	ND	32076315	64
SAVAGE	MT	24057382	87

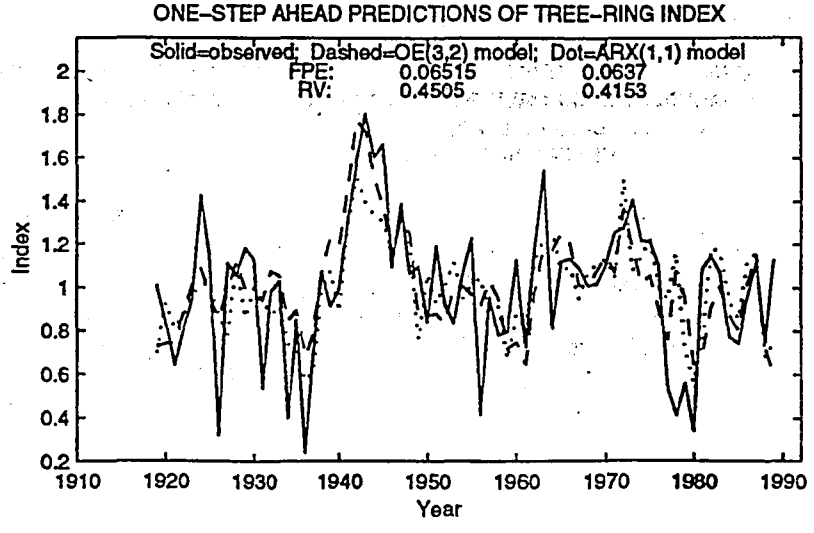












14 KDD Killdeer-Dvirnak ND

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1777								86	114	94
1780	104	97	114	84	113	137	167	114	98	102
1790	119	100	78	42	55	67	76	68	89	88
1800	58	127	87	97	107	130	140	141	76	79
1810	109	121	86	91	98	130	88	55	65	62
1820	97	118	120	83	109	99	153	143	153	118
1830	125	115	137	67	85	108	56	78	73	102
1840	130	101	57	108	106	117	121	117	96	96
1850	127	131	134	143	140	111	95	102	111	93
1860	109	110	97	73	61	70	95	83	80	73
1870	84	84	89	152	81	81	77	97	82	93
1880	112	109	96	83	89	105	81	66	74	83
1890	83	103	96	96	88	83	82	89	87	104
1900	76	100	106	107	113	112	105	105	90	114
1910	99	93	108	109	116	70	109	97	95	113
1920	89	88	116	141	132	104	94	104	121	103
1930	100	72	119	120	103	120	86	80	88	109
1940	101	119	133	105	106	107	74	97	106	113
1950	105	87	77	122	99	109	95	126	98	103
1960	79	73	78	121	110	116	103	86	83	131
1970	124	95	108	102	91	107	104	105	123	118
1980	88	95	129	113	98	75	84	86	80	101
1990	84									

Number of samples

	0	1	2	3	4	5	6	7	8	9
								1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	2	2	2
	2	2	2	2	2	2	2	2	3	5
	5	5	5	5	5	5	6	7	7	7
	8	8	9	9	10	11	11	11	11	12
	12	12	12	13	13	13	13	13	13	13
	15	15	15	15	15	15	15	16	16	16
	16	16	16	16	16	16	16	16	16	16
	16	17	17	18	18	18	18	18	18	18
	18	18	18	18	18	18	18	18	18	18
	18	18	18	19	20	20	20	20	20	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	22	23	23
	24	24	24	24	25	25	26	27	27	27
	27	27	27	27	27	27	28	28	29	30
	30	30	30	30	30	30	30	30	30	30
	30	30	30	30	30	30	30	30	30	30
	30	30	30	30	30	30	30	30	30	30
	30	30	29	29	28	28	28	28	28	28
	28	28	28	28	28	28	28	28	28	28
	28	28	28	28	28	28	28	28	28	28
	27									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: KDD.RWL
42 SERIES IN FILE, 10 NOT USED
CORE MASK: 12345678901234567890123456789012345678901234567890
12121212120101121212121110000110000112 12

DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
5 SPECIAL (NON-DEFAULT) CURVE FITS
32 CORES, 19 TREES IN FINAL CHRONOLOGY

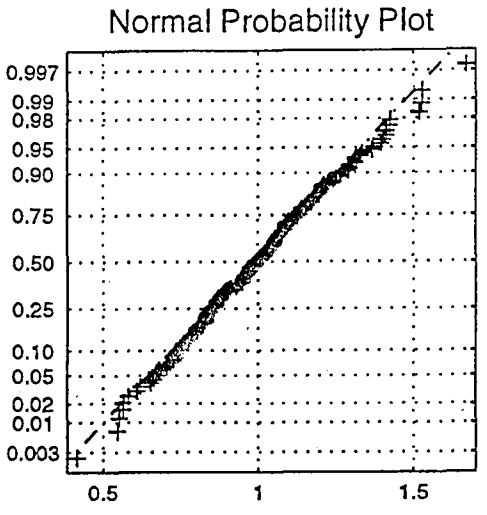
REMARKS

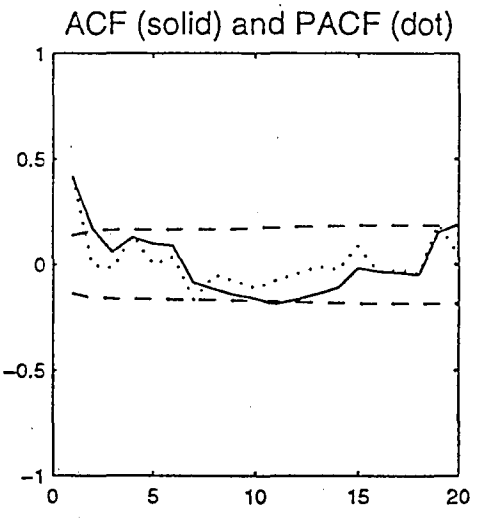
Private land in west-central North Dakota, 5 km west of Killdeer, North Dakota. Chronology species -- bur oak. Sampled trees are from very gentle slopes just above draws. Steeper slopes farther away from draws are devoid of oaks. The site is grazed by cattle. Oldest sample (inner ring, 1777) is growing in the open on a southwest-facing slope. Trees 7-10 might have been affected by watering since about the 1930s. This is the site of the Killdeer Battle, where in 1864 General Sully battled a band of Sioux Indians.

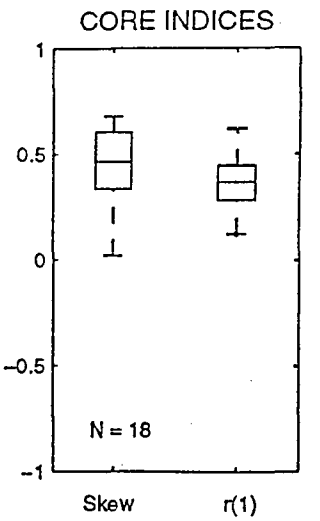
KILLDEER-DVIRNAK

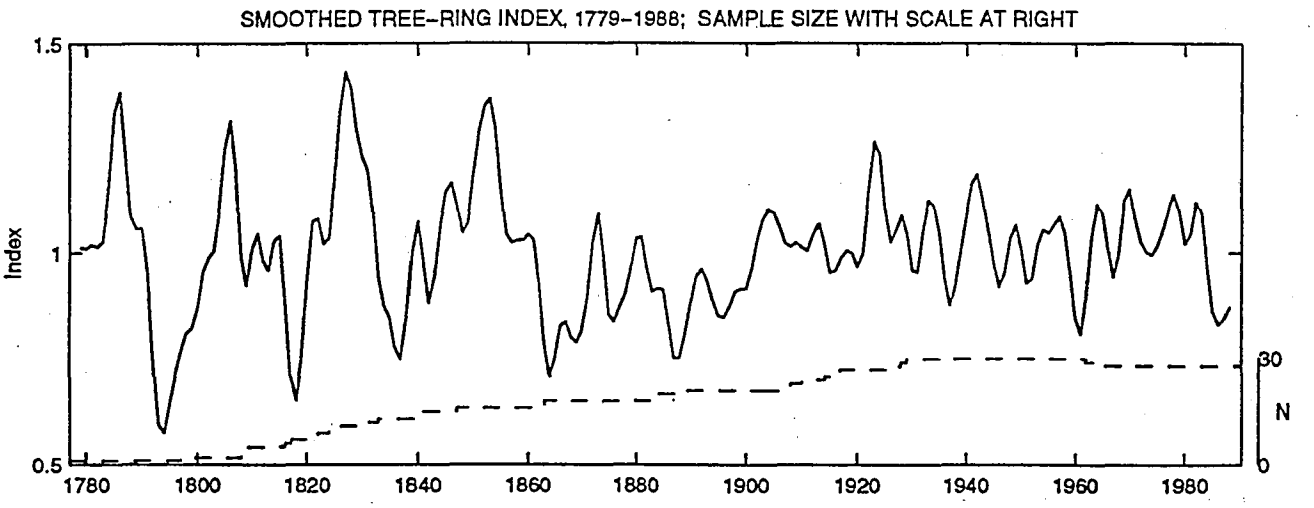
Climate Stations and Distances to Tree-Ring Site:

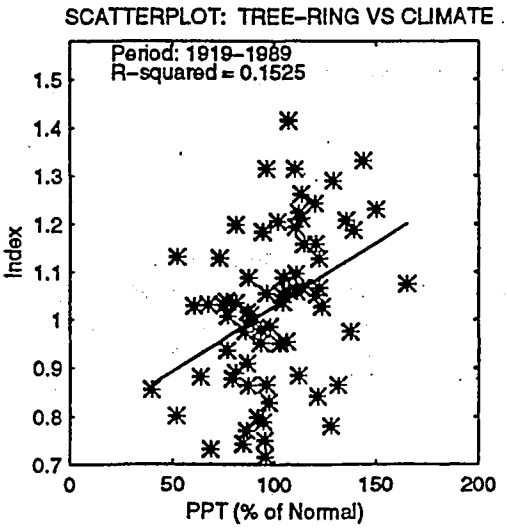
	State	ID	Distance (km)
DICKINSON EXP ST	ND	32072188	61
RICHARDTON ABBEY	ND	32077530	76
NEW ENGLAND	ND	32076315	98

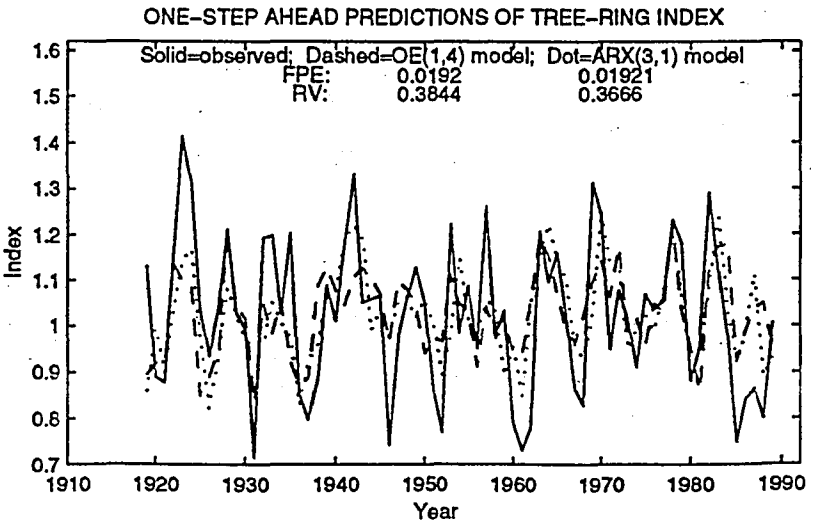












15 CRS Cross Ranch -- Sanger Unit ND

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1788									140	128									1	1
1790	117	113	99	87	119	114	111	130	88	92	1	1	1	2	2	2	2	2	3	3
1800	51	92	107	109	111	173	124	125	58	56	3	3	3	3	3	4	4	4	4	4
1810	96	98	110	131	86	131	84	77	53	62	4	4	4	4	4	4	4	4	4	4
1820	63	76	75	73	113	135	140	115	108	126	4	4	4	4	4	5	5	5	5	5
1830	134	134	133	85	107	96	97	111	106	92	6	7	7	7	7	7	7	7	7	7
1840	120	118	69	90	84	108	75	75	76	96	7	7	7	7	7	8	8	8	8	8
1850	132	119	134	153	114	119	124	124	112	91	8	8	8	8	8	8	8	8	8	8
1860	93	102	115	97	103	103	101	81	78	45	8	8	8	8	8	8	8	8	8	8
1870	55	70	72	85	73	70	77	77	77	73	8	8	8	8	8	8	8	8	8	8
1880	82	76	89	75	85	109	93	81	98	105	8	8	8	8	8	8	8	8	8	8
1890	133	131	119	95	83	87	69	70	73	80	8	8	8	8	8	8	8	8	8	8
1900	67	79	86	90	107	112	106	124	126	120	9	9	9	10	10	10	11	12	12	12
1910	105	93	144	122	123	79	112	82	102	123	12	12	12	12	13	14	14	14	14	14
1920	104	93	110	107	110	117	99	113	105	97	14	15	15	15	15	15	15	15	15	15
1930	99	97	106	104	87	112	79	83	98	118	15	15	15	15	15	15	15	15	15	15
1940	120	125	132	112	84	107	72	99	95	105	15	15	15	15	15	15	15	15	15	15
1950	104	95	73	104	97	113	104	108	95	95	15	15	15	15	15	15	15	15	15	15
1960	98	80	98	112	91	88	98	95	103	119	15	15	15	15	15	15	15	15	15	15
1970	120	98	109	92	96	98	105	106	121	110	15	15	15	15	15	15	15	15	15	15
1980	82	101	125	105	102	91	114	100	83	91	14	14	14	14	14	14	14	14	14	14
1990	97										14									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: CRS.RWL
25 SERIES IN FILE, 10 NOT USED
CORE MASK: 12345678901234567890123 45
00000120121212101210100
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
15 CORES, 9 TREES IN FINAL CHRONOLOGY

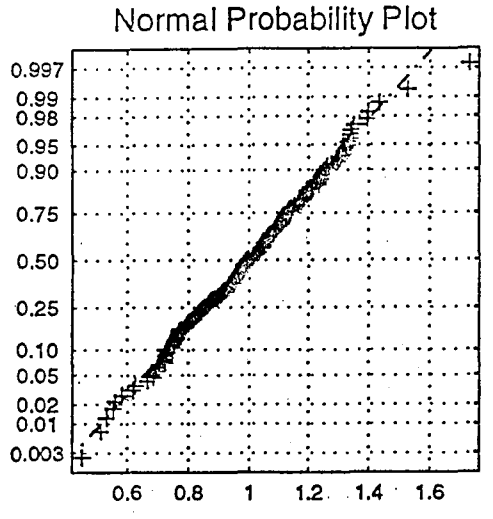
REMARKS

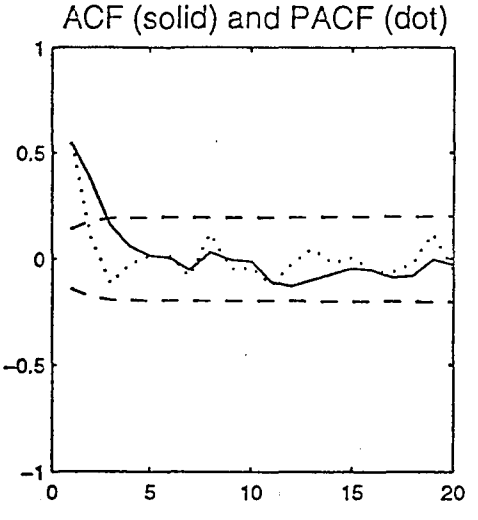
Private land in south-central North Dakota, 62 km northwest of Bismark, North Dakota. Chronology species -- bur oak. The site contains a spotty distribution of mostly even-aged bur oak along two major drainages. Upland and lowland trees were sampled. The older-looking trees were toward the lower slopes, and the oldest sampled tree (inner ring, 1778) is from the bottomland. The area has been grazed by buffalo, and by cattle in the 1900s. Drought stress is evident, with many trees of different species dead or dying.

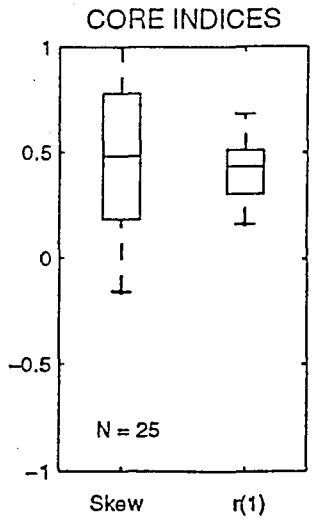
CROSS RANCH-SANGER UNIT

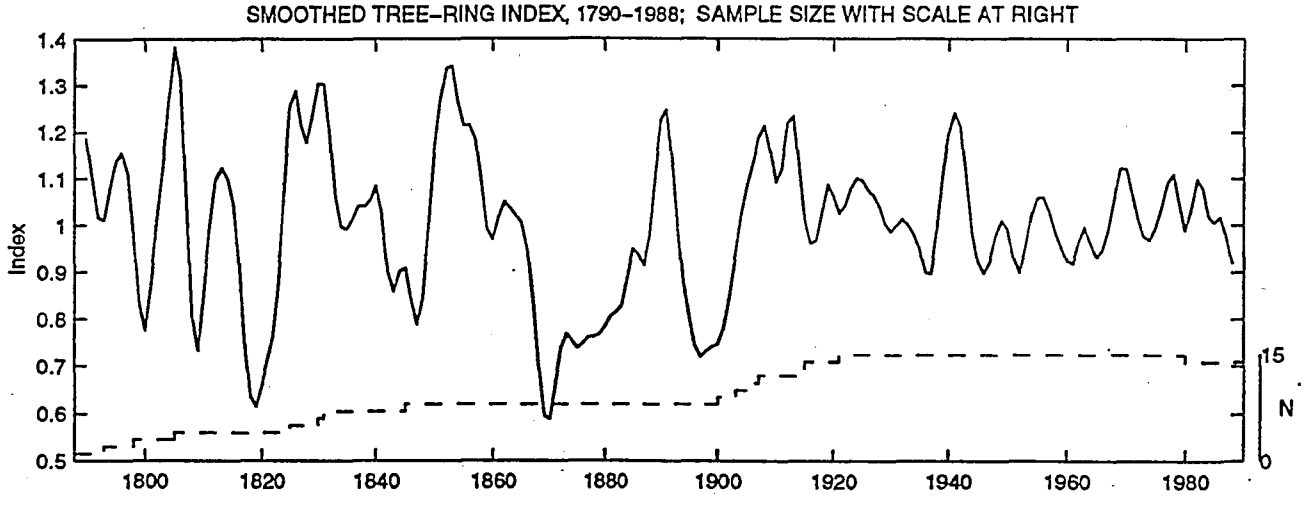
Climate Stations and Distances to Tree-Ring Site:

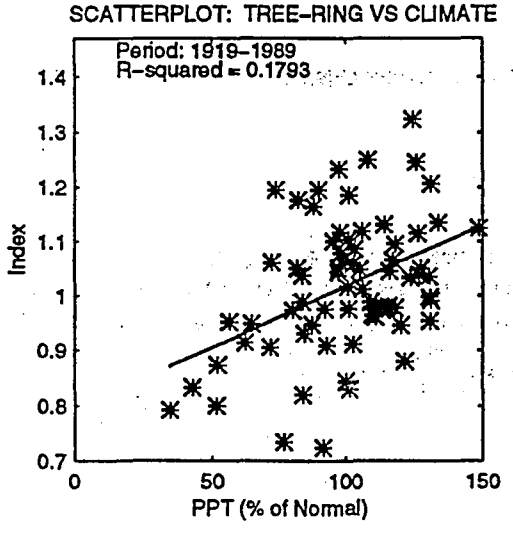
	State	ID	Distance (km)
MANDAN EXPERIMEN	ND	32085479	40
MOFFITT 3SE	ND	32058366	91

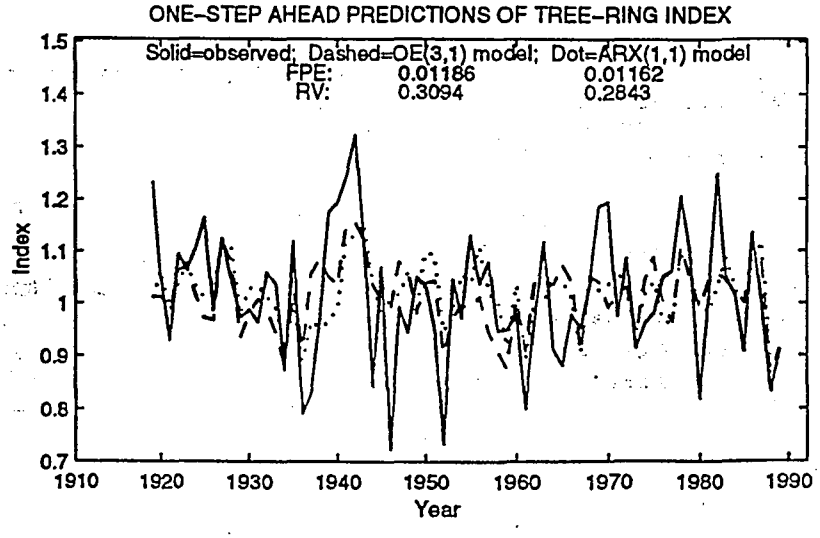












16 BRI Bear Island ND

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1801		109	54	113	91	89	115	110	108	129
1810	72	150	164	192	136	124	90	94	110	132
1820	99	78	87	79	92	80	88	110	98	74
1830	79	88	90	94	89	73	43	41	43	50
1840	69	88	59	98	78	122	130	133	124	142
1850	176	100	133	147	126	137	132	109	139	121
1860	164	142	95	103	120	57	76	114	137	96
1870	114	99	93	98	70	48	66	71	69	105
1880	112	97	132	84	68	100	118	120	97	58
1890	74	52	80	63	46	84	91	88	88	110
1900	82	129	114	94	107	113	94	115	115	125
1910	89	95	117	127	128	96	113	81	84	91
1920	89	99	107	124	114	110	113	121	118	100
1930	105	83	110	102	83	108	69	91	89	79
1940	85	104	122	95	98	112	78	112	107	122
1950	107	99	81	115	98	109	96	93	92	105
1960	102	88	81	103	100	103	90	72	85	115
1970	97	111	123	127	83	102	102	93	104	88
1980	76	109	134	118	100	99	103	77	58	97
1990	101									

Number of samples

	0	1	2	3	4	5	6	7	8	9
		1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	2
	2	2	2	2	2	3	3	3	3	3
	3	3	3	4	4	4	4	4	4	4
	4	4	4	4	4	4	4	4	4	4
	4	4	4	4	4	4	4	4	4	4
	5	5	5	5	5	5	5	5	5	5
	5	5	5	5	5	5	5	5	5	5
	5	5	5	5	5	5	5	5	5	5
	5	5	5	5	5	6	6	6	6	6
	6	6	6	6	6	6	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7	7	7	7	7	7	7	7	7	7
	7									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: BRI.RWL
11 SERIES IN FILE, 4 NOT USED
CORE MASK: 12345678901
12002001112
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
1 SPECIAL (NON-DEFAULT) CURVE FIT
7 CORES, 4 TREES IN FINAL CHRONOLOGY

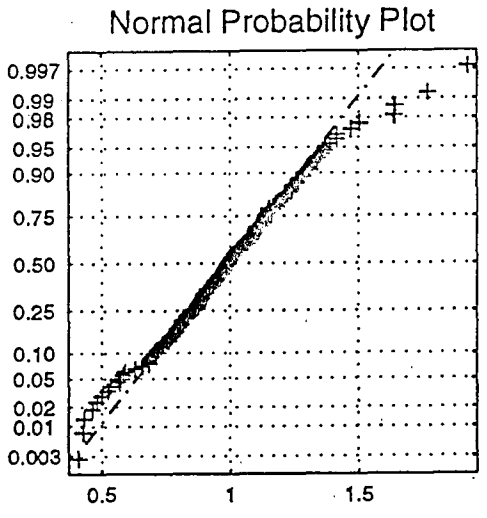
REMARKS

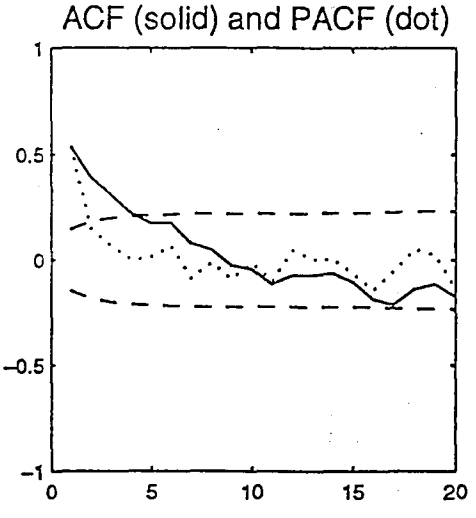
Private land in the Turtle Mountains, along the Canadian border in north-central North Dakota, 21 km north of Bottineau. Chronology species -- bur oak. Bear Island is on Lake Metigoshe, and rises only about 10 m feet above the lake. The site is a prairie pothole region with glacial till, and many wet spots and seeps. Also at the site are decadent stands of oak, elm, birch and poplar, and mostly other species that tolerate moisture. The few oaks are found along the shoreline. Fires swept through the area in late 1890s, but the islands escaped burn.

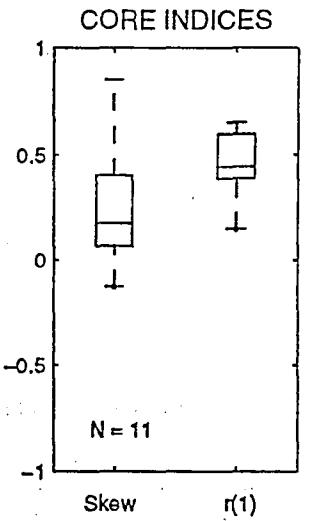
BEAR ISLAND

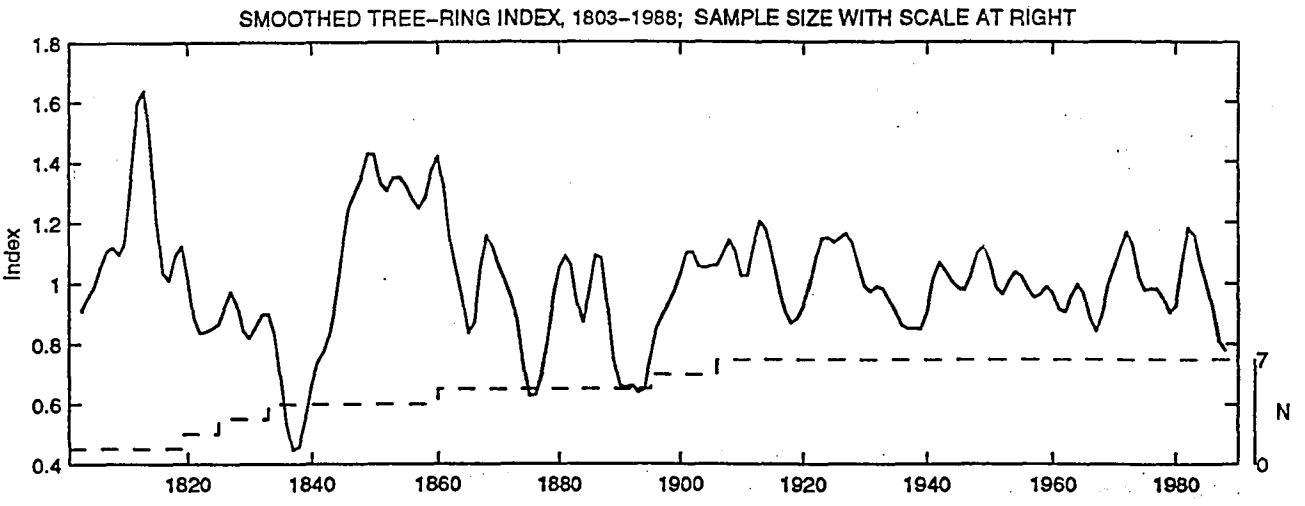
Climate Stations and Distances to Tree-Ring Site:

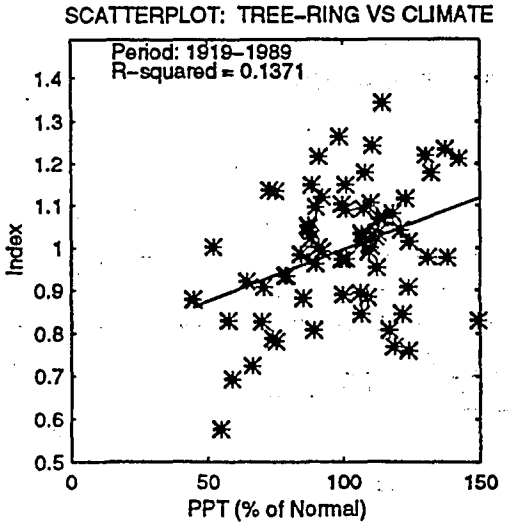
	State	ID	Distance (km)
BOTTINEAU	ND	32020941	19
WILLOW CITY	ND	32029445	39
TOWNER 2NE	ND	32026792	72

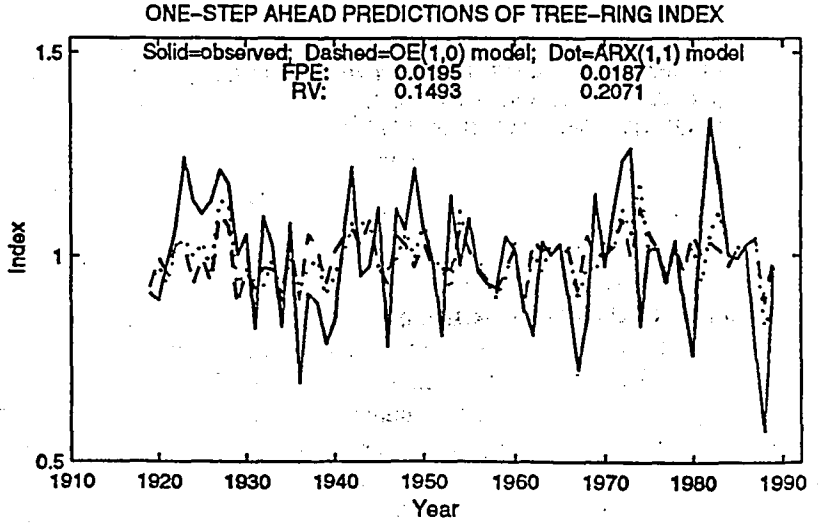












17 MAI Masonic Island ND

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1676							112	98	109	56							1	1	1	1
1680	44	30	41	47	51	159	126	118	71	68	1	1	1	1	1	1	1	1	1	1
1690	120	79	68	75	88	73	72	53	61	80	1	1	1	1	1	1	1	2	2	2
1700	60	47	45	42	46	39	40	38	58	49	2	2	2	2	2	2	2	2	2	2
1710	85	121	103	83	99	124	144	146	45	106	2	2	2	2	2	2	2	2	2	2
1720	138	99	145	183	201	156	156	271	239	259	2	2	2	2	2	2	2	2	2	2
1730	153	145	146	148	166	132	132	141	135	99	2	2	2	2	2	2	2	2	2	2
1740	104	111	107	56	72	89	88	97	89	126	2	2	2	2	2	2	2	2	2	2
1750	110	125	117	103	122	80	67	77	135	103	2	2	2	2	2	2	2	2	2	2
1760	261	223	67	56	57	59	45	43	57	67	2	2	2	2	2	2	2	2	2	2
1770	47	49	71	58	43	80	48	67	73	71	2	2	2	2	2	2	2	2	2	2
1780	112	62	85	69	102	94	98	170	132	102	2	2	2	2	2	2	2	2	2	2
1790	73	88	107	99	131	94	109	116	101	146	2	2	2	2	2	2	2	2	2	2
1800	121	139	86	89	94	93	111	124	72	78	2	2	2	2	2	2	2	2	2	2
1810	72	66	84	119	85	114	75	64	74	75	2	2	2	2	2	2	2	2	2	2
1820	97	112	120	84	119	105	98	138	155	112	2	2	2	2	2	2	2	2	2	2
1830	137	114	135	108	142	101	79	73	90	83	2	2	2	2	3	4	4	4	4	4
1840	96	114	76	93	89	86	120	93	116	120	4	4	4	4	4	4	4	4	4	4
1850	143	128	133	148	130	98	135	105	85	87	5	5	5	5	5	5	5	5	5	6
1860	109	113	86	71	78	54	71	73	78	78	6	6	6	6	6	6	6	6	6	6
1870	104	99	93	116	68	91	93	88	78	121	6	6	6	6	6	6	6	6	6	6
1880	130	106	118	82	64	112	102	89	95	70	6	6	6	6	6	6	6	6	6	6
1890	84	105	115	116	103	114	101	86	96	121	6	6	6	6	6	6	6	6	6	6
1900	72	119	121	106	99	135	100	115	114	152	6	6	6	6	6	6	6	6	6	6
1910	75	87	112	127	128	80	107	91	100	94	6	6	6	6	6	6	6	6	6	6
1920	104	89	108	137	113	80	92	100	120	91	6	6	6	6	6	6	6	6	6	6
1930	90	57	103	90	79	113	76	116	95	95	6	6	6	6	6	6	6	6	6	6
1940	87	106	114	99	103	105	65	104	109	133	6	6	6	6	6	6	6	6	6	6
1950	121	107	82	135	90	116	109	119	84	100	6	6	6	6	6	6	6	6	6	6
1960	99	69	92	107	105	109	87	77	87	117	6	6	6	6	6	6	6	6	6	6
1970	105	115	109	134	89	112	106	83	103	85	6	6	6	6	6	6	6	6	6	6
1980	72	79	116	113	92	89	115	93	88	108	6	6	6	6	6	6	6	6	6	6
1990	106										6									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: MAI.RWL
6 SERIES IN FILE, 0 NOT USED
CORE MASK: 123456
121212
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
6 CORES, 3 TREES IN FINAL CHRONOLOGY

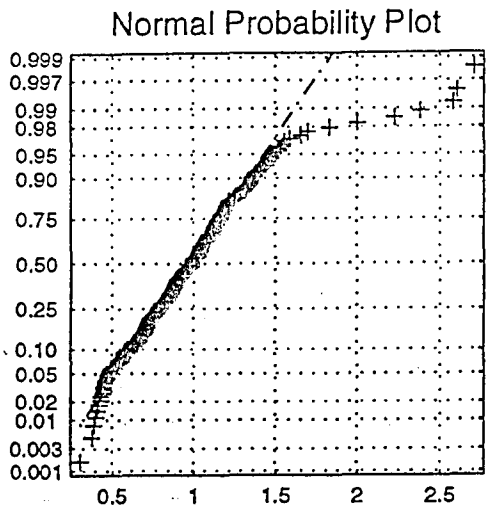
REMARKS

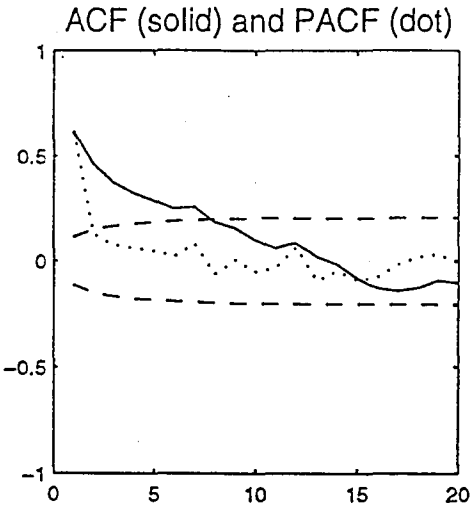
Private and State Park land in the Turtle Mountains, along the Canadian border in north-central North Dakota, 19 km north of Bottineau, North Dakota. Chronology specie -- bur oak. This chronology was built by merging core samples from sites MAI (Masonic Island) and MET (Lake Metigoshe State Park). The MAI samples are from a small privately owned island that rises only about 10 m above Lake Metigoshe. The MAI site type is similar to that of Bear Island (see chronology BRI). The MET sample is from a small pocket of oaks surrounded by aspen about 2 km east of Lake Metigoshe. This is a wet site containing many springs. Many of the smaller oaks at MET had suckered from a common base, giving 2-5 trees in a cluster today. The glacial till is mainly sand and gravel that wicks moisture to the surface. The MET sample was the oldest in the chronology (inner ring, 1676). Fires swept through the area in late 1890s, but the islands escaped burn.

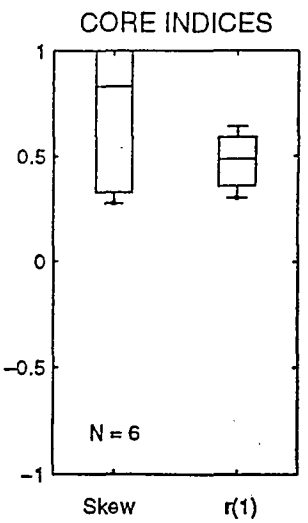
MASONIC ISLAND

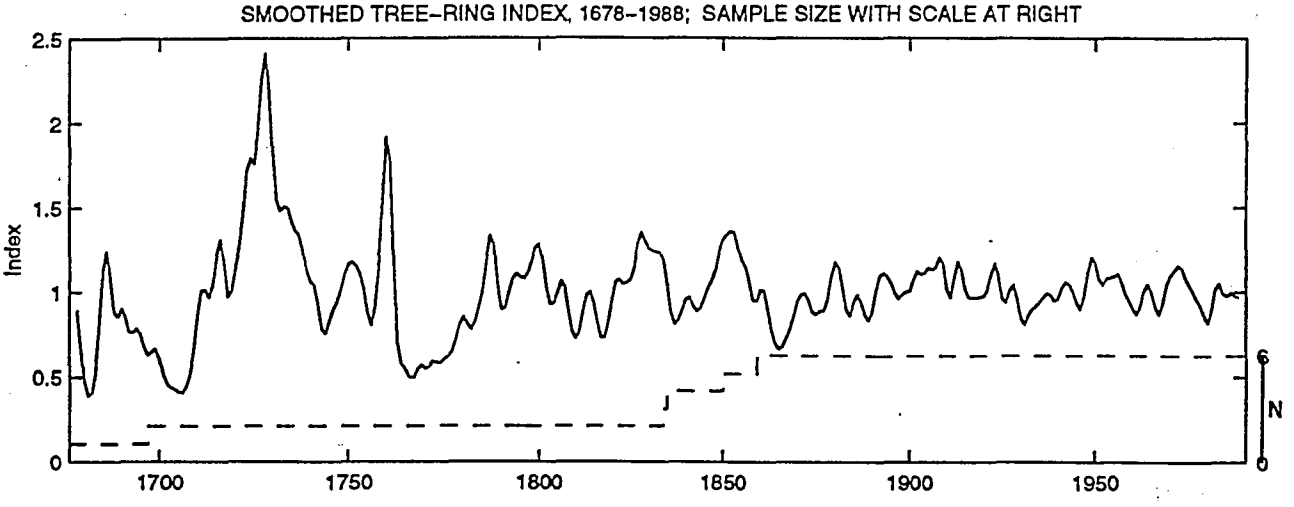
Climate Stations and Distances to Tree-Ring Site:

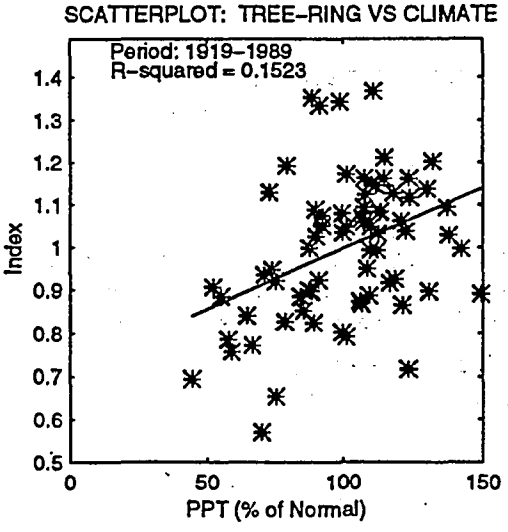
	State	ID	Distance (km)
BOTTINEAU	ND	32020941	19
WILLOW CITY	ND	32029445	38
TOWNER 2NE	ND	32026792	71

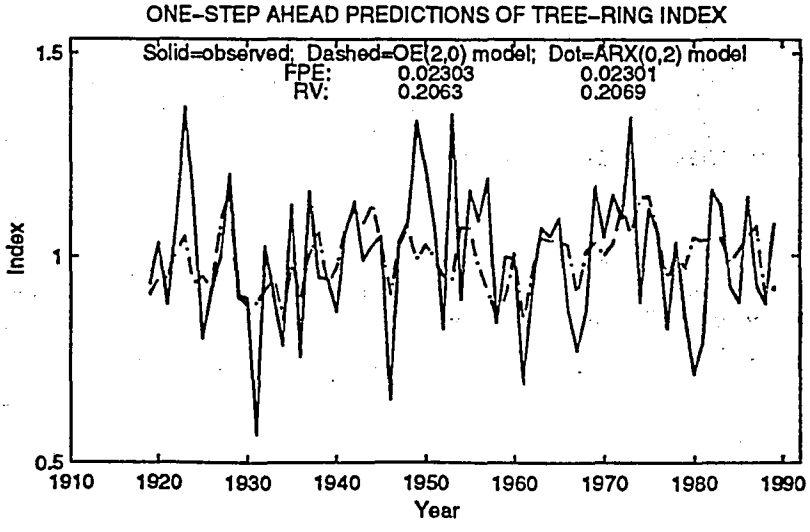












18 ROC Rockerville SD

Date	Tree-Ring Indices										Number of samples									
	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1717								168	104	50								1	1	1
1720	71	89	78	112	107	114	94	124	135	161	1	1	1	1	1	1	1	2	2	2
1730	115	83	72	78	66	51	56	70	75	103	2	2	2	2	2	2	2	2	2	2
1740	100	85	58	63	60	71	83	123	105	79	2	2	2	2	2	3	3	4	4	4
1750	56	85	108	98	105	167	112	68	53	61	4	4	4	4	4	4	4	4	4	4
1760	64	95	85	89	96	157	135	155	126	121	4	4	4	4	4	4	4	4	4	4
1770	91	169	147	148	127	139	124	108	81	90	4	4	4	4	4	4	4	4	4	4
1780	103	96	82	71	100	75	62	68	132	148	5	5	5	5	5	5	5	5	5	5
1790	148	97	95	112	112	131	87	120	109	116	5	5	5	5	5	5	5	5	5	5
1800	82	94	127	130	110	137	104	106	88	69	5	5	5	5	5	5	5	6	6	6
1810	90	102	117	124	116	121	112	111	103	116	6	6	6	6	6	6	6	6	6	6
1820	101	112	89	96	96	98	160	112	111	121	6	6	6	6	6	6	6	6	6	6
1830	125	111	132	98	90	98	84	81	64	72	6	6	6	6	6	6	6	6	6	6
1840	87	106	62	70	77	75	93	77	68	92	6	6	6	6	6	6	6	6	6	6
1850	93	121	112	138	117	69	80	73	74	70	6	6	6	6	6	6	6	6	6	6
1860	67	73	74	81	85	60	83	79	85	99	6	6	6	6	6	6	6	6	6	6
1870	83	83	91	96	78	99	85	69	92	96	6	6	6	6	6	6	6	6	6	6
1880	107	105	153	95	111	135	99	136	130	115	6	6	6	6	6	6	6	6	6	6
1890	130	114	138	116	97	103	89	92	89	82	6	6	6	6	6	6	6	7	7	8
1900	98	108	108	111	118	118	95	130	118	113	8	8	8	8	8	8	8	8	8	8
1910	93	84	115	97	89	87	107	106	105	85	8	8	8	8	8	8	8	8	8	8
1920	89	99	115	139	121	150	122	114	85	108	8	8	8	8	8	8	8	8	8	8
1930	99	87	127	129	88	122	84	94	80	77	8	8	8	8	8	8	8	8	8	8
1940	62	74	111	103	79	106	94	108	105	129	8	8	8	8	8	8	8	8	8	8
1950	105	91	99	126	97	90	89	120	95	100	8	8	8	8	8	8	8	8	8	8
1960	75	61	70	73	84	80	74	75	85	93	8	8	8	8	8	8	8	8	8	8
1970	111	98	90	103	79	93	116	115	134	113	8	8	8	8	8	8	8	8	8	8
1980	105	116	126	103	105	88	124	126	102	95	8	8	8	8	8	8	8	8	8	8
1990	112										8									

CHRONOLOGY MAKEUP

RING-WIDTH FILE: ROC.RWL
10 SERIES IN FILE, 2 NOT USED
CORE MASK: 1234567890
0110121212
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
0 SPECIAL (NON-DEFAULT) CURVE FITS
8 CORES, 5 TREES IN FINAL CHRONOLOGY

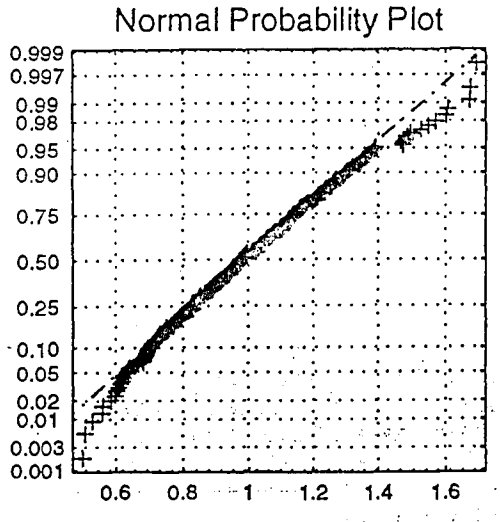
REMARKS

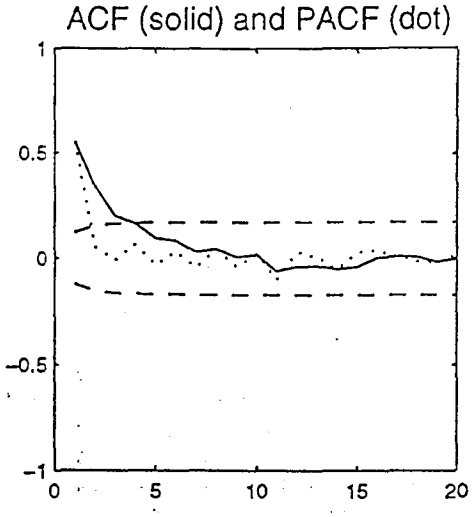
Black Hills National Forest, in the central Black Hills, 6 km southeast of Hill City, South Dakota. Chronology species -- bur oak. Samples are from open meadows in rocky terrain with thin soils. The site has been heavily logged since about 1987. The oldest sampled trees are within 100 m of each other on 20-degree north-facing slope. These upland trees have excellent ring sequences beginning in 1717 and 1727 -- both sampled to pith.

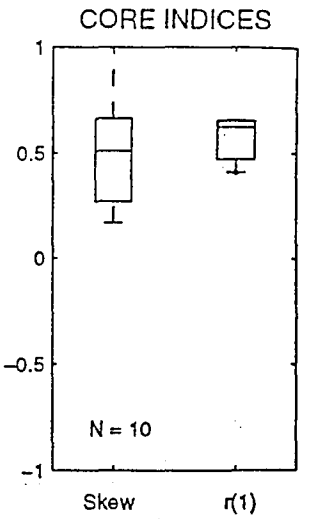
ROCKERVILLE

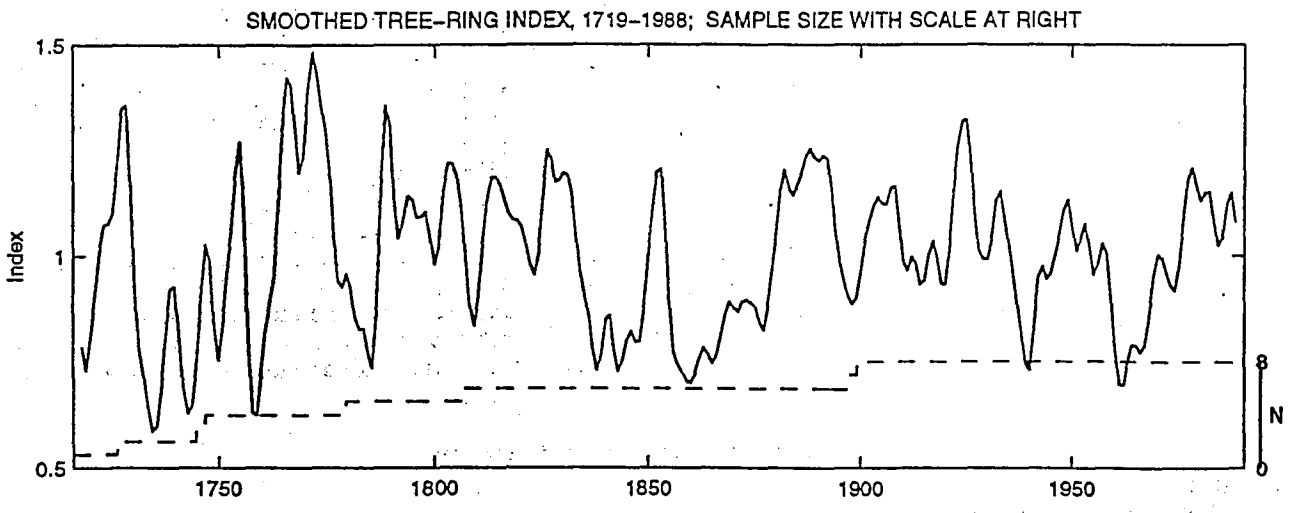
Climate Stations and Distances to Tree-Ring Site:

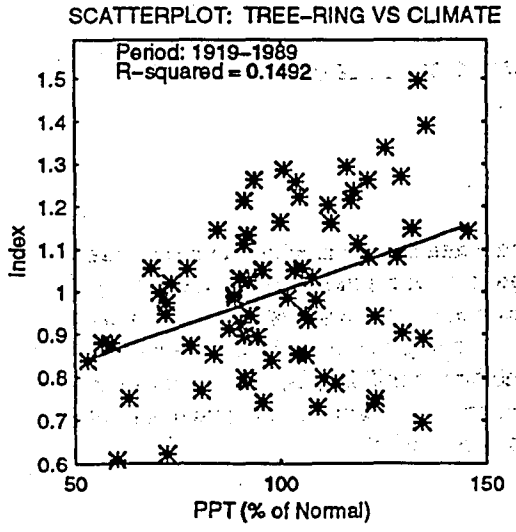
	State	ID	Distance (km)
RAPID CITY	SD	39056947	18
HOT SPRINGS	SD	39044007	58
NEWCASTLE	WY	48076660	68

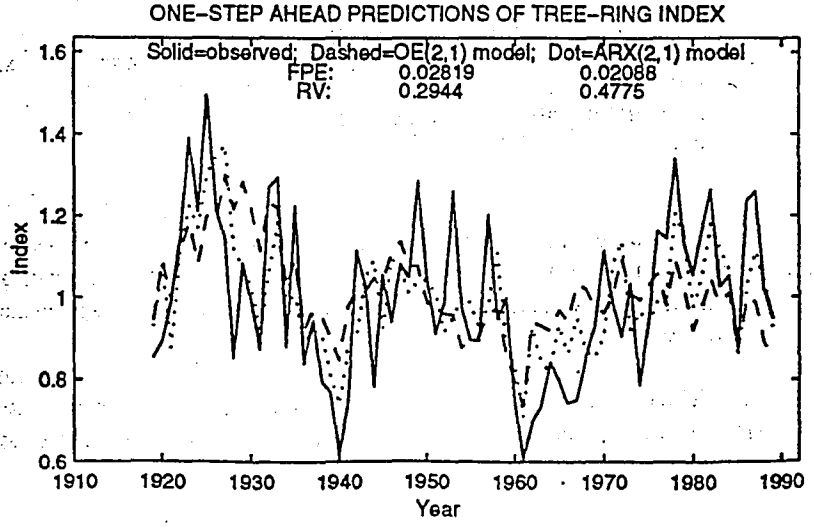












19 REN Reno Gulch SD

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1600	67	118	111	116	114	77	75	65	85	126	5	5	5	5	5	5	5	5	5	5
1610	149	133	156	161	125	178	182	174	56	101	7	7	7	8	8	8	8	8	8	8
1620	68	96	92	83	96	106	105	97	109	116	8	8	8	8	8	8	8	8	8	8
1630	116	109	104	109	75	91	115	42	61	74	8	8	8	8	8	8	8	8	8	8
1640	100	122	149	132	141	139	97	107	82	132	8	8	8	8	8	8	8	8	8	8
1650	96	101	84	115	97	110	120	107	115	111	8	8	8	8	8	8	8	8	8	8
1660	83	100	54	61	84	97	83	91	49	124	8	8	8	8	8	8	8	8	8	8
1670	127	112	124	146	117	99	113	89	84	55	8	8	8	8	8	8	8	8	8	8
1680	85	96	87	114	109	116	124	135	135	112	9	9	9	9	9	9	9	9	9	9
1690	103	120	124	106	115	107	56	95	59	99	9	9	9	9	9	9	9	9	9	9
1700	91	88	102	103	96	73	41	95	72	103	9	9	9	9	9	9	10	10	10	10
1710	78	65	54	79	76	81	97	78	54	95	10	10	10	10	10	10	10	10	10	10
1720	57	61	82	73	68	82	116	127	118	142	10	11	11	11	11	12	12	12	12	12
1730	109	110	108	122	57	69	57	94	116	138	12	12	12	12	12	12	12	12	12	12
1740	190	99	89	95	101	84	93	88	126	113	12	13	13	13	14	15	15	15	15	15
1750	126	122	135	73	89	90	71	50	39	60	15	15	15	15	15	15	15	15	15	15
1760	65	91	106	143	125	138	138	153	142	131	15	15	15	15	15	15	15	15	16	16
1770	90	138	96	115	128	125	115	126	163	120	16	16	16	17	17	17	17	17	17	17
1780	96	56	70	96	80	64	75	78	75	77	17	17	17	17	17	17	17	17	17	18
1790	98	95	103	110	104	126	125	105	106	129	18	18	18	18	18	19	19	19	19	19
1800	109	137	121	127	105	109	118	88	87	72	19	19	19	19	19	19	19	19	19	19
1810	94	108	109	135	117	106	112	94	121	120	19	19	19	19	19	19	19	19	19	19
1620	121	136	110	73	88	112	97	113	101	115	19	19	19	19	19	19	19	19	19	19
1830	105	94	110	119	111	125	133	123	112	112	20	20	20	20	20	20	20	20	20	20
1840	120	105	106	101	118	89	87	72	50	104	20	21	21	21	21	21	21	21	21	21
1850	93	112	81	91	101	69	41	78	106	89	21	21	21	21	21	21	21	21	21	21
1860	71	78	89	68	61	32	52	78	83	101	21	21	22	22	22	22	22	22	22	22
1870	75	81	55	95	103	91	74	89	119	133	22	22	22	22	22	22	22	22	22	22
1880	103	99	127	121	113	125	123	114	137	116	22	22	22	22	22	22	22	22	22	22
1890	132	135	109	91	98	101	87	100	95	112	22	22	22	22	22	22	22	22	22	22
1900	96	101	100	126	137	130	125	139	142	109	22	22	22	22	22	22	22	22	22	22
1910	107	19	79	94	104	129	139	104	116	101	22	22	22	22	22	22	22	22	22	22
1920	83	91	115	101	100	112	100	121	112	107	22	22	22	22	22	22	22	22	22	22
1930	125	56	113	97	32	92	43	81	98	24	22	22	22	22	22	22	22	22	22	22
1940	78	93	100	117	111	145	159	128	96	108	22	22	22	22	22	22	22	22	22	22
1950	92	88	100	108	78	108	77	93	96	76	22	22	22	22	22	22	22	22	22	22
1960	90	29	109	106	113	168	127	118	131	135	22	22	22	22	22	22	22	22	22	22
1970	101	102	116	131	67	145	136	67	127	110	22	22	21	21	21	21	21	21	21	21
1980	77	79	96	110	124	22	114	109	72	87	21	20	20	20	20	18	18	18	16	16
1990	152	114									15	13								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: REN.RWL
32 SERIES IN FILE, 10 NOT USED
CORE MASK: 12345678901234567890123456789012
12012012123102120012121101001200
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
8 SPECIAL (NON-DEFAULT) CURVE FITS
22 CORES, 12 TREES IN FINAL CHRONOLOGY

REMARKS

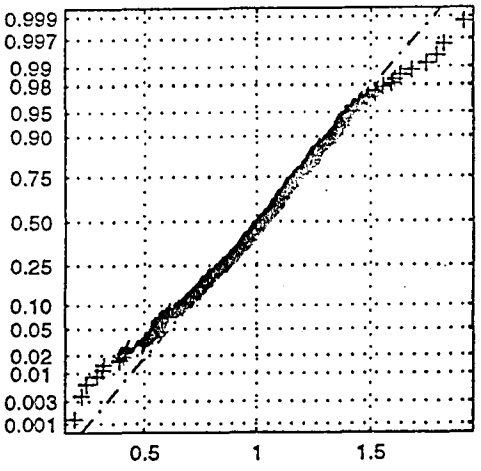
Black Hills National Forest, in the south-central Black Hills of southwestern South Dakota, 3 km southeast of Hill City, South Dakota. Chronology species -- ponderosa pine. The site is open-growth, with a moderate slope (30-45 degree) and west-northwest aspect. At the base of the site are large Precambrian boulders. The soil is thin and covered by a thick mat of pine needles over most of the site. At least 2 fires have swept through, and the site has been logged at some unknown date between the two fires. Many tree have dry rot. In addition to living trees, a few stumps were cored. The oldest sampled tree (inner ring, 1281) is growing on a rocky site, is only about 9 m tall, and has huge gnarled branches and platy bark. See Appendix B for listing of chronology before 1600.

RENO GULCH

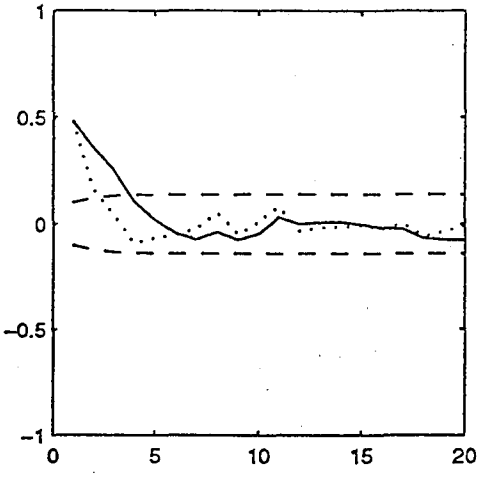
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
RAPID CITY	SD	39056947	34
NEWCASTLE	WY	48076660	49
HOT SPRINGS	SD	39044007	55

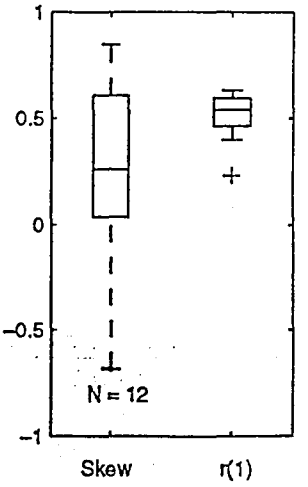
Normal Probability Plot



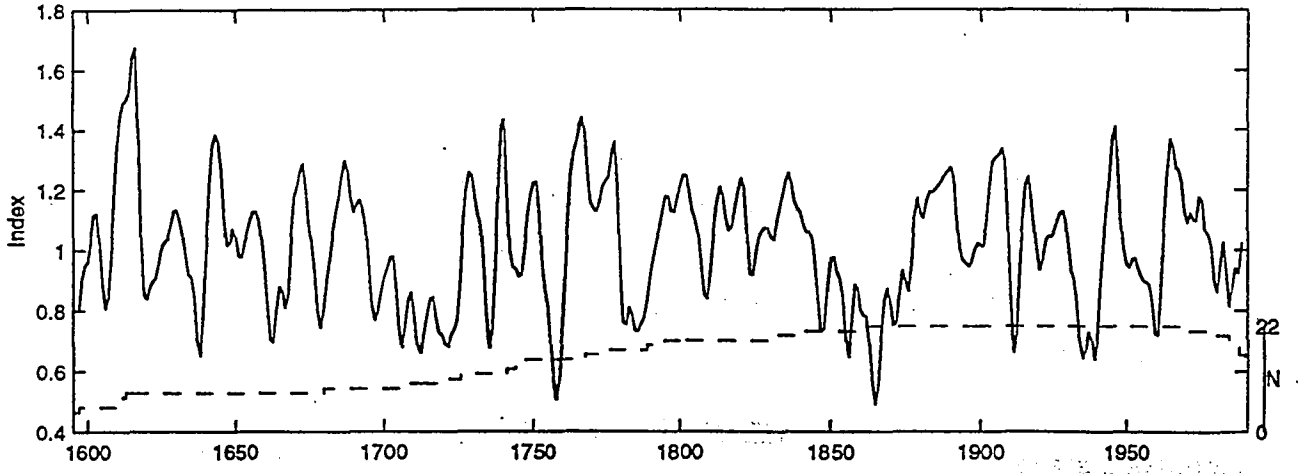
ACF (solid) and PACF (dot)



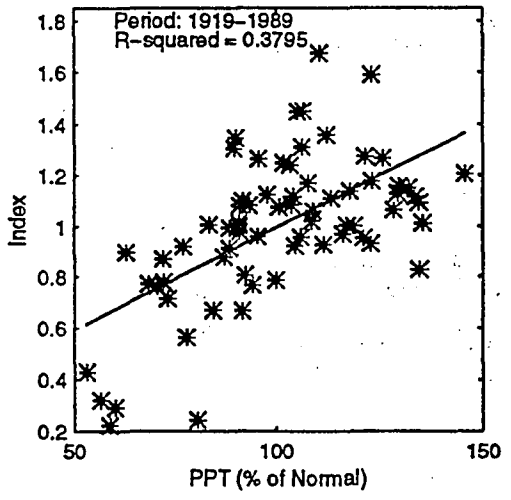
CORE INDICES



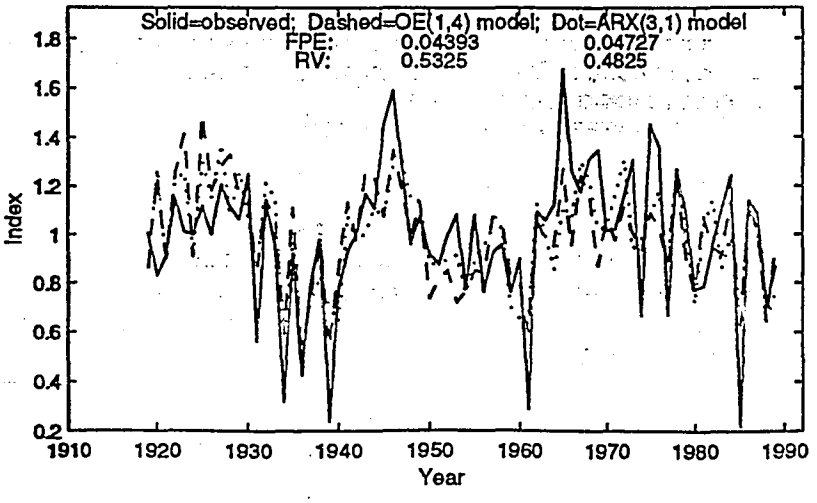
SMOOTHED TREE-RING INDEX, 1597-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



20 SSP Stone State Park IA

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1796							65	88	87	96
1800	126	89	85	107	51	104	73	61	60	54
1810	89	85	109	103	136	140	90	110	106	89
1820	89	103	143	103	159	105	140	170	174	140
1830	112	112	79	79	52	79	73	73	78	43
1840	85	85	98	106	100	100	61	105	78	98
1850	112	93	124	134	109	96	94	99	95	88
1860	97	134	147	114	82	101	107	87	104	118
1870	98	83	115	104	84	119	114	104	78	91
1880	90	95	105	86	102	90	90	135	127	119
1890	111	137	127	94	72	62	119	104	113	87
1900	80	102	108	136	115	108	103	105	100	117
1910	86	74	98	93	64	95	109	96	75	94
1920	108	95	89	107	126	84	84	121	122	108
1930	104	70	103	81	91	98	76	83	87	94
1940	111	123	110	102	127	133	64	71	80	120
1950	119	106	97	81	99	95	93	109	88	101
1960	120	103	125	94	90	90	97	112	93	130
1970	117	102	114	94	93	102	80	79	117	105
1980	72	67	104	104	103	112	121	109	89	96
1990	118	120								

Number of samples

	0	1	2	3	4	5	6	7	8	9
							1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	2	2	2	2	2	2
	2	2	2	2	2	2	2	2	2	2
	4	4	4	4	4	4	4	4	4	4
	4	4	4	4	4	4	4	4	4	4
	4	4	4	5	6	6	6	7	7	7
	8	9	10	10	10	10	11	12	12	14
	14	14	15	16	16	17	17	17	17	18
	18	18	18	18	18	18	18	19	20	20
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	21	21	21	21	21	21	21	21	21
	21	18								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: SSP.RWL
26 SERIES IN FILE, 5 NOT USED
CORE MASK: 12345678901234567890123456
12011212121212121212000012
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH MEAN
10 SPECIAL (NON-DEFAULT) CURVE FITS
21 CORES, 11 TREES IN FINAL CHRONOLOGY

REMARKS

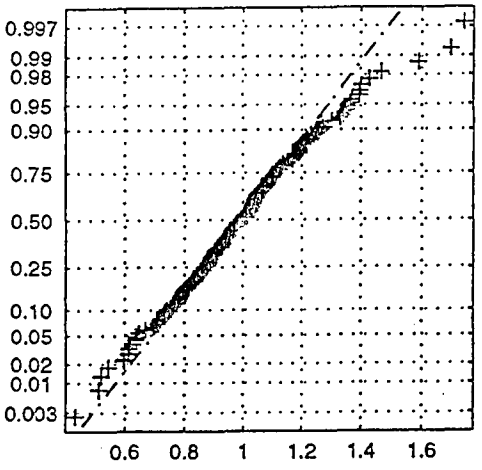
Stone State Park, in the far northwestern corner of Iowa, 3 km northwest of Sioux City, Iowa. Chronology species -- bur oak. Sampled trees are from rich, deep, black soil on slopes above several meandering creeks. The overstory is almost all hardwood, with a minor component of eastern red cedar. The ground cover is dense grass and poison ivy, and much of the site is mowed. Rot is common in these oaks. Fire scars occur on some trees. The oldest tree (inner ring, 1796) is huge: height 18 m, diameter 101 cm; this tree is growing on a 10-degree south-facing slope about 6 m above a road.

STONE STATE PARK

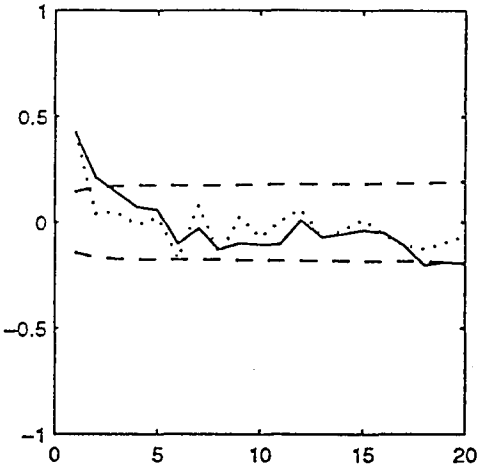
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
LE MARS	IA	13014735	37
WAKEFIELD	NE	25038915	46
HARTINGTON	NE	25033630	66

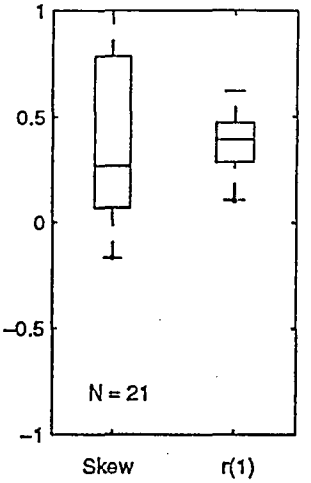
Normal Probability Plot



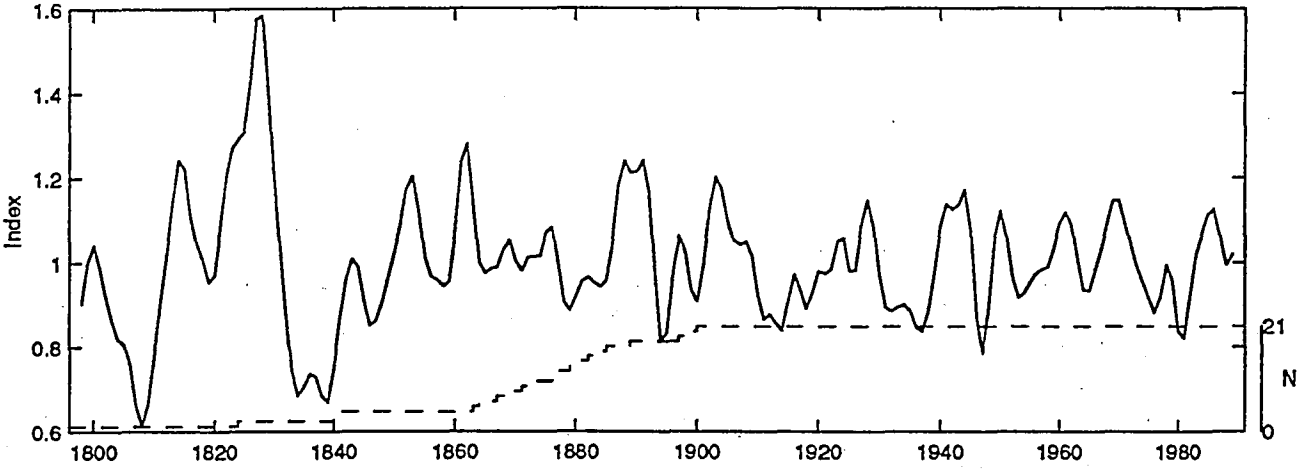
ACF (solid) and PACF (dot)



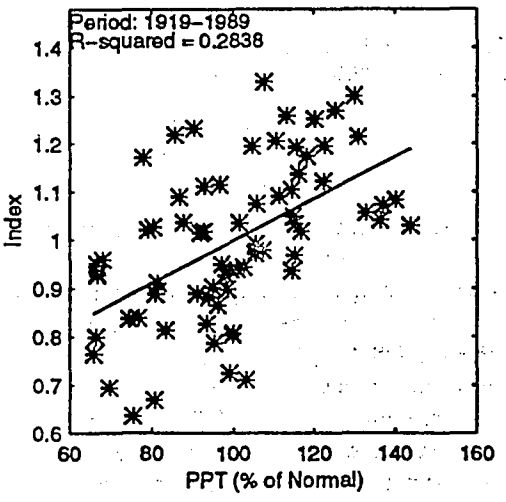
CORE INDICES



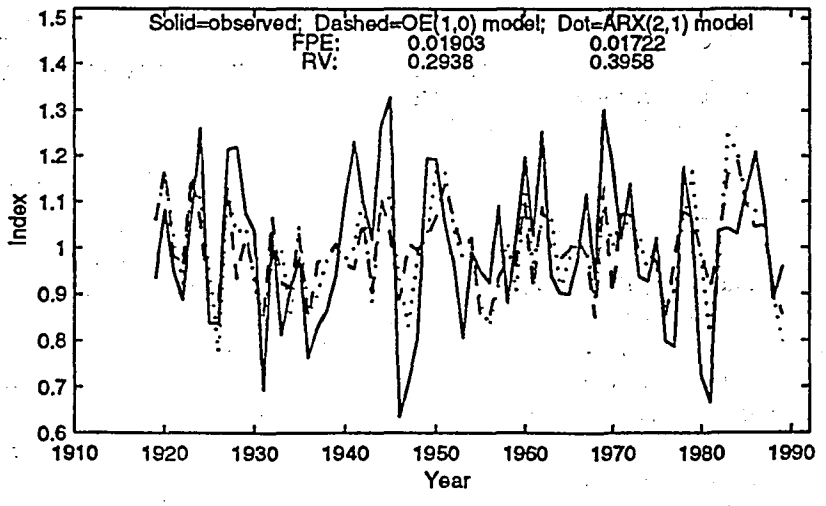
SMOOTHED TREE-RING INDEX, 1798-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



21 BHM Buckhorn Mountain SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1600	106	194	156	130	151	67	132	157	127	167
1610	140	171	172	174	97	194	148	174	124	124
1620	84	110	139	79	51	89	99	81	88	84
1630	54	65	48	64	62	61	61	30	59	70
1640	68	81	99	129	125	82	68	98	46	72
1650	60	88	65	56	72	66	97	86	105	86
1660	75	92	73	115	103	91	125	89	54	109
1670	138	108	108	122	102	99	135	115	117	74
1680	113	106	113	157	148	131	135	124	117	101
1690	63	92	104	88	112	150	103	102	99	126
1700	105	89	116	94	82	80	50	115	65	102
1710	123	67	88	116	92	105	117	55	58	129
1720	90	61	107	99	72	91	137	114	100	122
1730	83	93	90	112	48	61	51	106	126	114
1740	134	46	70	63	94	48	69	81	116	73
1750	97	103	127	92	158	99	38	35	52	39
1760	61	85	89	114	110	146	166	153	148	115
1770	110	144	97	138	135	116	103	126	133	84
1780	100	94	104	122	106	66	92	102	90	86
1790	97	71	99	109	81	95	99	88	76	110
1800	69	103	101	125	98	87	97	79	55	58
1810	78	102	87	109	109	82	144	78	81	93
1820	99	114	88	61	74	114	109	115	138	151
1830	164	124	117	146	145	110	120	120	93	107
1840	136	126	133	125	145	103	114	107	44	122
1850	77	88	79	124	118	93	56	91	129	95
1860	69	75	110	48	69	72	75	76	84	105
1870	64	74	52	92	90	96	60	77	105	102
1880	43	70	116	116	103	131	140	140	172	147
1890	123	140	119	95	118	74	42	74	80	101
1900	92	93	114	118	136	131	132	163	146	150
1910	80	22	107	112	112	130	107	81	107	79
1920	77	87	104	100	77	91	70	93	75	86
1930	81	66	109	97	26	78	77	92	104	33
1940	64	109	121	127	130	143	132	145	78	108
1950	84	73	78	95	62	111	108	104	109	98
1960	79	55	99	131	122	153	97	109	110	126
1970	114	113	137	132	78	108	82	54	88	85
1980	67	109	128	138	173	21	147	110	62	86
1990	111	108								

Number of samples

	0	1	2	3	4	5	6	7	8	9
1600	1	1	1	1	1	1	1	1	1	1
1610	2	2	2	2	2	2	2	2	2	2
1620	2	2	2	2	2	2	2	2	2	2
1630	2	2	2	2	2	2	2	2	2	2
1640	3	3	3	3	3	3	3	3	3	3
1650	3	3	3	3	3	3	3	3	3	3
1660	3	3	3	3	3	3	3	3	3	5
1670	6	7	7	7	7	8	9	9	9	9
1680	9	9	9	9	9	10	10	10	10	10
1690	10	10	10	11	11	11	11	11	11	11
1700	11	11	12	13	13	14	14	14	14	14
1710	14	14	14	14	14	14	14	14	14	14
1720	14	14	14	14	14	14	14	14	14	14
1730	14	14	14	14	14	14	14	14	14	14
1740	14	14	14	14	14	14	14	14	14	14
1750	15	16	16	16	16	16	16	16	16	16
1760	16	16	16	16	16	17	17	18	19	19
1770	21	21	21	21	21	22	24	24	25	25
1780	25	25	25	25	25	26	26	26	26	26
1790	26	26	27	27	27	27	27	27	27	27
1800	27	27	27	27	27	27	27	27	27	27
1810	27	27	27	27	27	27	27	27	27	27
1820	27	27	27	27	27	27	27	27	27	27
1830	29	29	29	29	29	29	29	29	29	29
1840	29	29	29	29	29	29	29	29	29	29
1850	29	29	29	29	29	29	29	29	29	29
1860	29	29	29	29	29	29	29	29	29	29
1870	29	29	29	29	29	29	29	29	29	29
1880	29	29	29	29	29	29	29	29	29	29
1890	29	29	29	29	29	29	29	29	29	29
1900	29	29	29	29	29	29	29	29	29	29
1910	29	29	29	29	29	29	29	29	29	29
1920	29	29	29	29	29	29	29	29	29	29
1930	29	29	29	29	29	29	29	29	29	29
1940	29	29	29	29	29	29	29	29	29	29
1950	29	29	29	29	29	29	29	29	29	29
1960	29	29	29	29	29	29	29	29	29	29
1970	29	29	29	29	29	29	29	29	29	29
1980	29	29	29	29	28	28	28	28	28	28
1990	28	25								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: BHM.RWL
33 SERIES IN FILE, 2 NOT USED
CORE MASK: 12345678901234567890123456789012 3
1212121212121212111211212001121212
DEFAULT FIRST CURVE FIT: MODIFIED NEG. EXPONENTIAL OR STRAIGHT LINE WITH NEG. SLOPE
DEFAULT SECOND CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
19 SPECIAL (NON-DEFAULT) CURVE FITS
31 CORES, 17 TREES IN FINAL CHRONOLOGY

REMARKS

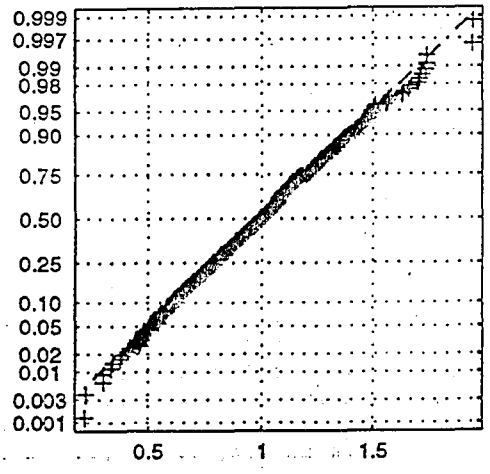
Black Hills National Forest, in the south-central Black Hills, 2 km north of Custer, South Dakota. Chronology species -- ponderosa pine. The site is an open-growth stand on a spur ridge of Buckhorn Mountain. The stand had been commercially thinned years ago. Soils are thin, slopes 20-45 degrees, and aspect variable. The oldest tree (inner ring, 1600) is growing on a south exposure nestled among rocks above a precipitous drop; this tree has a bonsai appearance, with twisted limbs; the diameter is only 43 cm. A site very near this one, possibly including some of the same trees, was collected on September 16, 1980, by T. Harlan and D. Meko. That chronology was used in a published precipitation reconstruction (J. Clim. and Appl. Met., 22(1), 1983). The earlier chronology, deck CUS640 in the Arizona Tree-Ring Lab. database, covers 1577-1979. Ten ponderosa pine from a nearby site on Buckhorn Mountain were also sampled on 6-17-91 by D. Meko and S. Deisch; those samples were not worked up into a chronology because they were too young.

BUCKHORN MOUNTAIN

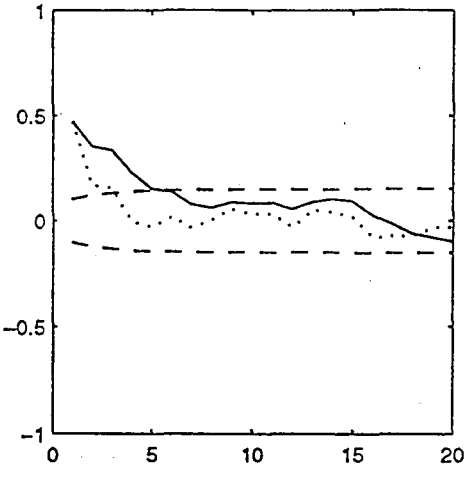
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
HOT SPRINGS	SD	39044007	41
RAPID CITY	SD	39056947	42
NEWCASTLE	WY	48076660	50

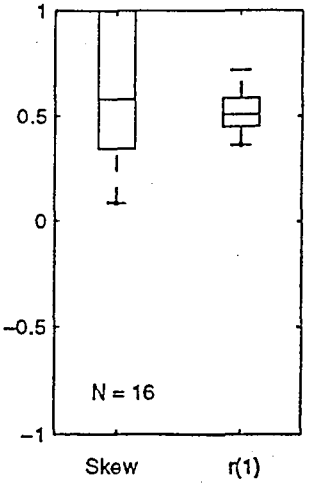
Normal Probability Plot



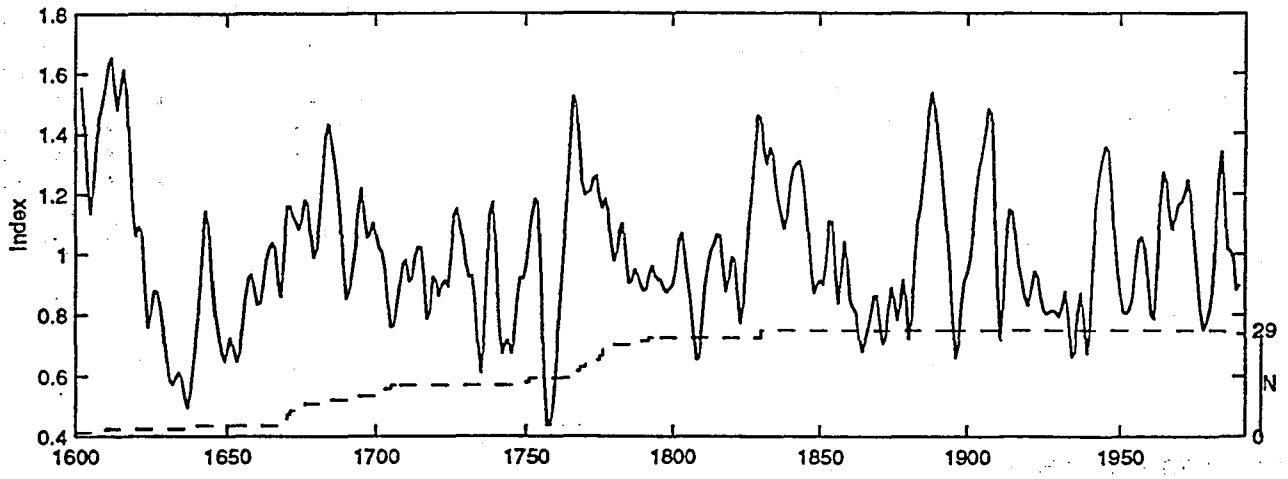
ACF (solid) and PACF (dot)



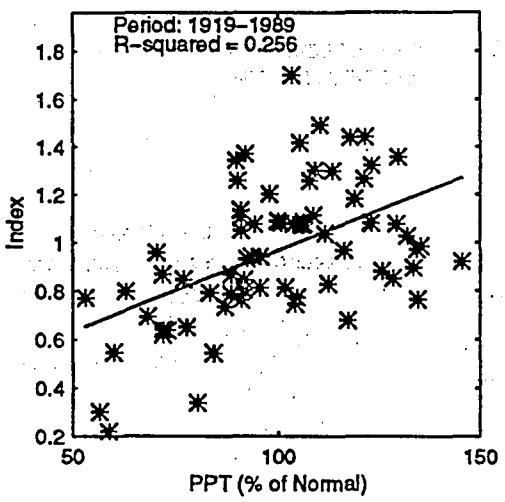
CORE INDICES



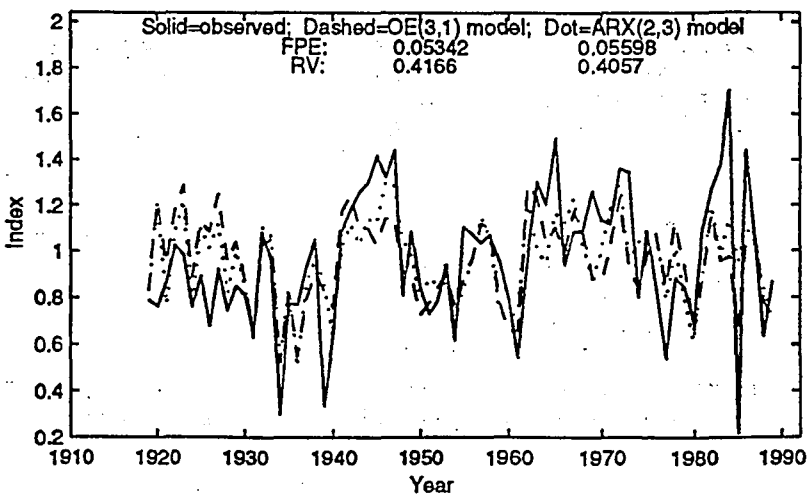
SMOOTHED TREE-RING INDEX, 1602-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



22 CED Cedar Butte Pine SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1646							87	108	103	70
1650	128	113	135	60	101	104	154	152	123	144
1660	118	100	105	101	87	36	10	21	52	38
1670	88	88	116	105	135	139	209	118	109	46
1680	52	110	168	210	164	94	93	136	126	95
1690	112	123	129	58	140	131	124	91	58	97
1700	122	141	134	81	90	74	58	41	41	71
1710	76	34	37	56	73	89	105	48	57	82
1720	79	67	95	103	101	98	114	163	156	200
1730	158	118	118	118	75	71	69	96	112	84
1740	124	55	88	64	95	89	106	155	158	68
1750	87	103	109	93	98	66	39	60	16	31
1760	31	48	59	119	133	103	115	86	153	53
1770	100	124	87	92	118	136	137	177	225	154
1780	131	126	114	133	99	64	107	87	126	62
1790	97	64	102	121	84	57	42	68	83	57
1800	51	58	78	126	120	116	128	118	82	73
1810	57	79	84	105	100	95	114	56	60	76
1820	92	119	54	99	79	86	89	102	166	191
1830	182	152	132	164	160	113	97	97	103	141
1840	145	107	143	103	174	66	94	52	55	106
1850	105	152	133	164	156	95	125	147	146	86
1860	104	86	94	48	33	44	59	70	107	98
1870	94	82	96	65	50	66	49	79	121	98
1880	59	115	155	151	140	151	122	99	157	130
1890	99	100	106	77	88	38	37	71	58	42
1900	13	58	63	101	61	83	121	130	111	123
1910	114	29	107	72	112	152	118	93	120	104
1920	99	116	146	159	199	183	165	187	103	99
1930	117	81	83	63	22	100	55	72	72	38
1940	68	69	120	58	79	85	88	138	127	83
1950	83	114	147	132	118	101	67	102	110	51
1960	132	84	107	123	76	101	104	126	139	113
1970	118	136	143	114	73	82	55	96	123	86
1980	56	90	135	125	126	34	95	103	113	69
1990	161	103								

Number of samples

Date	0	1	2	3	4	5	6	7	8	9
1646							1	1	1	1
1650	1	1	1	1	1	1	1	1	1	1
1660	1	1	1	1	1	1	1	1	1	1
1670	2	2	2	2	2	4	4	4	4	4
1680	4	5	6	6	6	6	6	6	6	6
1690	6	6	7	7	7	7	7	7	7	7
1700	7	7	7	7	7	7	7	7	7	7
1710	7	7	7	7	7	7	7	7	7	7
1720	7	7	7	7	7	7	7	8	8	8
1730	8	8	8	8	8	8	8	8	9	9
1740	9	9	9	9	9	9	9	9	9	9
1750	9	9	9	9	9	9	8	8	8	8
1760	8	8	8	8	8	8	8	8	8	8
1770	8	8	8	8	8	8	8	8	9	9
1780	9	8	8	8	8	9	9	9	9	9
1790	9	9	9	9	9	9	9	9	9	9
1800	9	9	9	9	9	9	9	9	9	10
1810	10	10	10	10	10	10	10	11	11	11
1820	11	11	11	11	11	11	11	11	11	11
1830	11	11	11	11	11	11	12	12	12	12
1840	12	12	12	13	13	13	13	13	13	13
1850	13	13	13	13	13	13	13	13	13	13
1860	13	13	13	13	13	13	13	13	13	13
1870	14	14	14	14	14	14	14	14	14	14
1880	14	14	14	14	14	14	14	14	14	14
1890	14	14	14	14	14	14	14	14	14	14
1900	14	14	14	14	14	14	14	14	14	14
1910	14	14	14	14	14	14	14	14	14	14
1920	14	14	14	14	14	14	14	14	14	14
1930	14	14	14	14	14	14	14	14	14	14
1940	14	14	14	14	14	14	14	14	14	14
1950	14	14	14	14	14	14	14	14	14	14
1960	14	14	14	14	14	14	14	14	14	14
1970	14	14	14	14	14	14	14	14	14	14
1980	14	14	14	14	14	14	14	14	14	14
1990	14	14								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: CED.RWL
16 SERIES IN FILE, 0 NOT USED
CORE MASK: 1234567890123456
1221212121212121
DEFAULT FIRST CURVE FIT: MODIFIED NEG. EXPONENTIAL OR STRAIGHT LINE WITH NEG. SLOPE
DEFAULT SECOND CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
6 SPECIAL (NON-DEFAULT) CURVE FITS
16 CORES, 8 TREES IN FINAL CHRONOLOGY

REMARKS

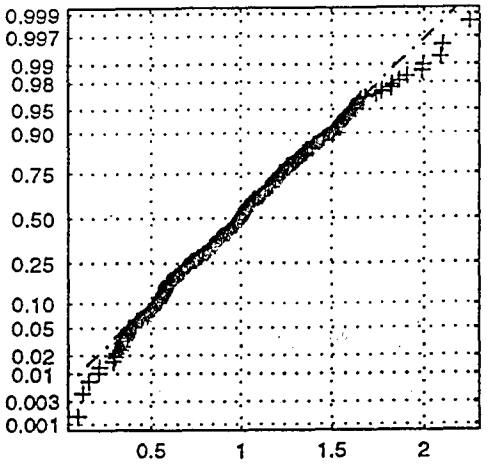
Private land in the badlands of south-central South Dakota, 26 km west of White River, South Dakota. Chronology species -- ponderosa pine. Samples are from thin soils on steep (30-60 degree) slopes. According to a local rancher, fire swept through this site at the turn of century, and the only area reportedly spared from major disturbance was this site. The oldest tree (inner ring, 1646) clings to the edge of a hillside on a 60-degree slope, 2 m above the bottom of a draw. This tree has platy bark, huge twisted limbs, a diameter of 50 cm, and large roots exposed on downhill side. A separate chronology was also developed for Rocky Mountain juniper at this site (see chronology CEJ). The oldest sampled juniper at the site (inner ring, 1691) is growing beside the oldest sampled ponderosa pine.

CEDAR BUTTE PINE

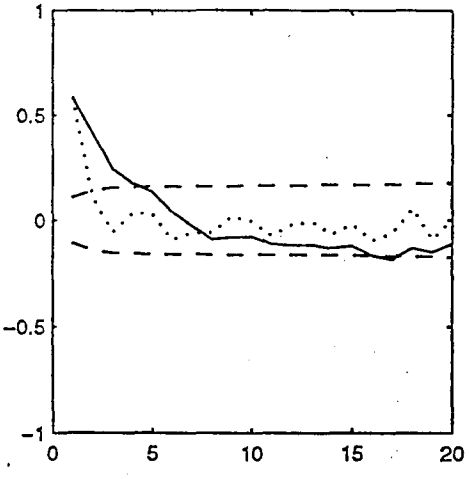
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
MURDO	SD	39065891	45
COTTONWOOD 2E	SD	39051972	72
MERRIMAN	NE	25025470	89

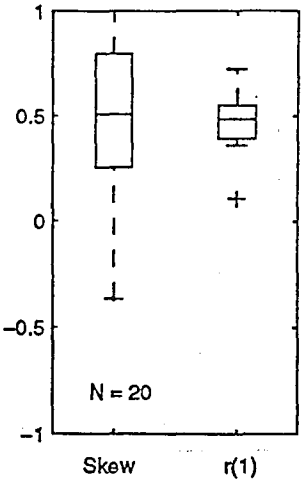
Normal Probability Plot



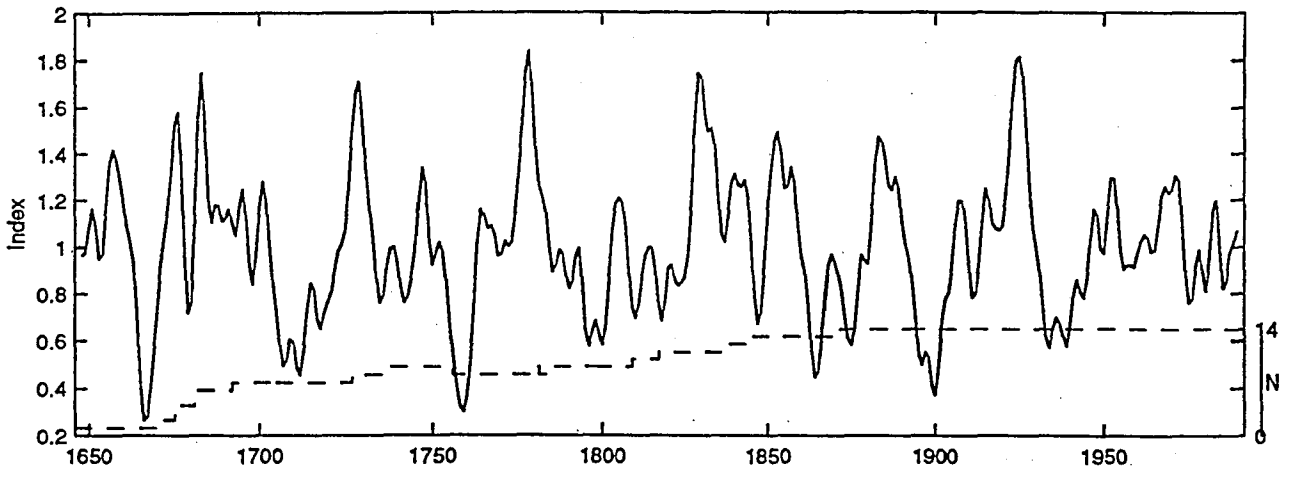
ACF (solid) and PACF (dot)



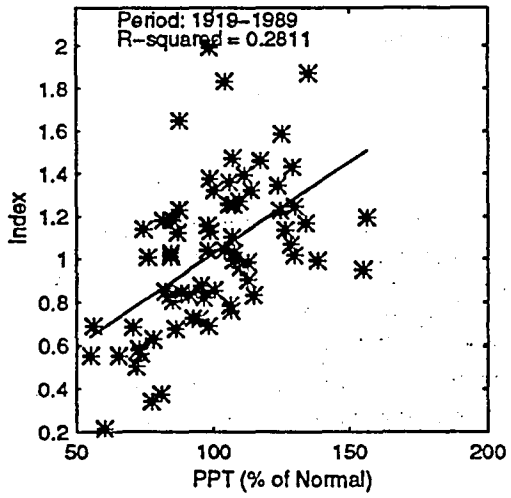
CORE INDICES



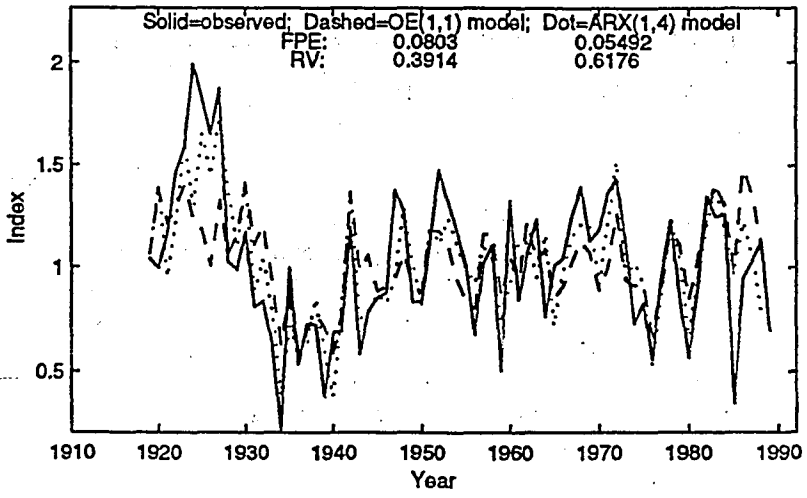
SMOOTHED TREE-RING INDEX, 1648-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



23 CED Cedar Butte Juniper SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1691		125	120	57	116	101	111	65	81	139
1700	200	258	161	111	106	101	48	43	54	143
1710	135	141	117	93	93	74	66	30	27	52
1720	111	55	92	145	109	115	84	92	76	188
1730	118	67	48	73	17	36	14	85	101	70
1740	124	17	53	51	110	138	177	211	160	65
1750	127	87	104	126	126	115	19	84	73	118
1760	90	164	140	247	183	58	102	88	83	40
1770	72	81	77	92	87	127	205	213	199	134
1780	114	86	88	104	107	72	138	157	128	59
1790	133	72	116	161	137	170	111	84	81	73
1800	22	21	57	70	101	108	68	75	43	95
1810	77	87	31	116	120	52	65	19	48	34
1820	62	133	87	70	96	114	106	133	142	150
1830	187	131	151	129	110	70	78	109	92	80
1840	92	82	114	40	85	58	86	69	45	73
1850	84	142	134	155	142	117	83	116	134	85
1860	105	91	98	73	57	68	76	153	151	160
1870	125	98	97	66	53	94	92	132	180	162
1880	98	77	149	130	112	150	105	77	71	85
1890	45	58	75	62	70	66	61	96	93	68
1900	33	21	108	140	110	138	149	158	125	97
1910	117	40	119	48	98	187	133	143	156	132
1920	144	116	157	135	155	146	79	119	75	101
1930	96	29	49	46	14	73	69	91	114	45
1940	67	70	131	76	87	103	83	108	102	82
1950	103	102	93	108	89	74	53	114	124	78
1960	118	89	147	119	103	127	107	168	144	68
1970	109	129	120	117	94	102	64	109	89	74
1980	56	109	117	105	118	62	123	129	93	57
1990	105	112								

Number of samples

	0	1	2	3	4	5	6	7	8	9
		1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1
	2	2	2	2	2	2	2	2	2	2
	2	2	2	2	2	2	2	2	2	2
	2	2	2	2	2	2	2	2	2	2
	2	2	2	2	2	2	2	2	2	2
	2	2	2	2	2	2	2	2	2	2
	2	2	2	3	3	3	3	3	3	3
	3	3	3	3	3	3	3	4	4	4
	4	4	4	4	4	4	5	5	5	5
	5	5	5	5	5	6	6	6	6	6
	6	6	6	6	8	8	8	8	8	8
	8	8	8	8	8	8	8	8	8	8
	8	8	8	8	8	8	8	9	9	9
	9	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	11	11	11	11	11
	11	11	11	11	11	11	11	11	11	11
	11	11	11	11	11	11	11	11	11	11
	11	11	11	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	10
	10	10	10	10	10	10	10	10	10	11
	11	11	11	11	11	11	11	11	11	11
	11	11	11	11	10	10	10	10	10	10
	10	10	10	9	9	9	9	9	9	9
	9	9								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: CEJ.RWL
16 SERIES IN FILE, 3 NOT USED
CORE MASK: 1234567890123456
1231200123120111
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT 67% OF SERIES LENGTH
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH THE MEAN
1 SPECIAL (NON-DEFAULT) CURVE FIT
13 CORES, 7 TREES IN FINAL CHRONOLOGY

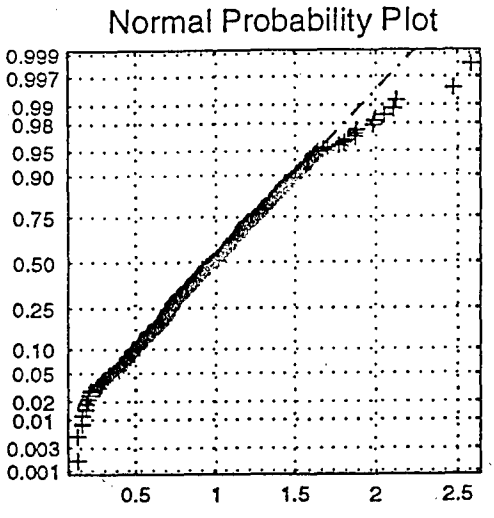
REMARKS

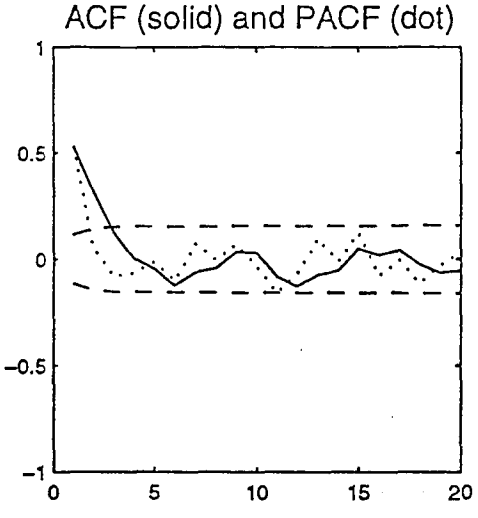
Private land in the badlands of south-central South Dakota, 26 km west of White River, South Dakota. Chronology species -- Rocky Mountain juniper. Samples are from thin soils on steep (30-60 degree) slopes. According to a local rancher, fire swept through this site at the turn of century, and "cedars" in the area were logged for fence posts. The only area reportedly spared from major disturbance was this site. Oldest tree (inner ring, 1691) clings to the edge of hillside on 60-degree slope 2 m above the bottom of a draw. The lower branches of this tree are dead, and the bark is gone from the west and north sides of trunk; the diameter is only diameter 21 cm. A separate ponderosa pine chronology was also developed at this (see chronology CED). The oldest sampled ponderosa pine (inner ring, 1646) was found growing beside the oldest juniper.

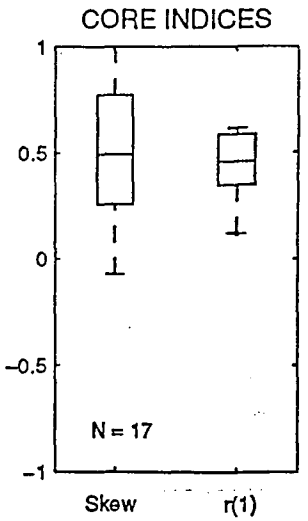
CEDAR BUTTE JUNIPER

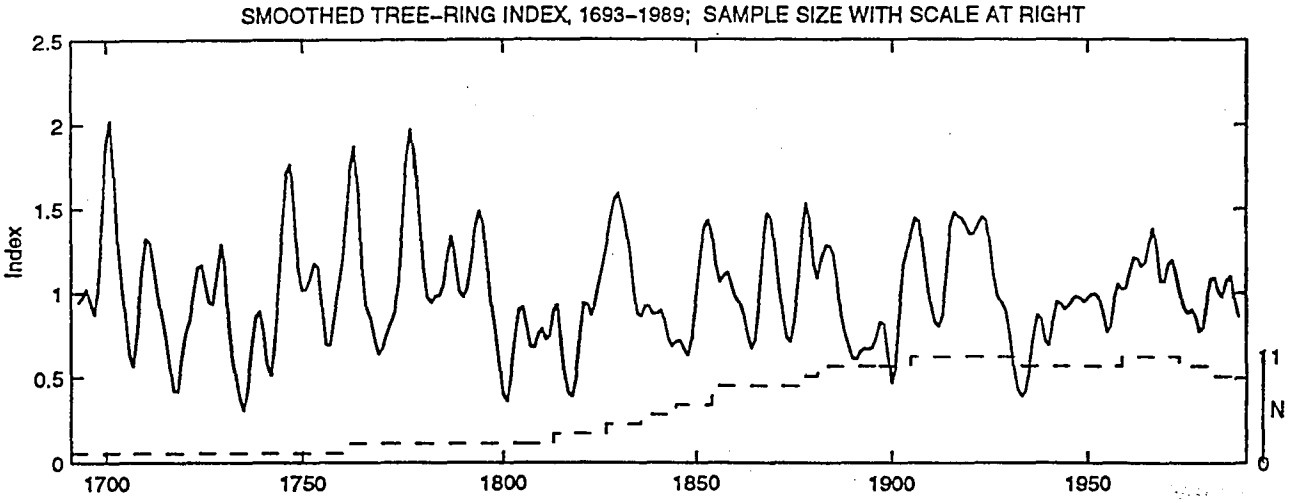
Climate Stations and Distances to Tree-Ring Site:

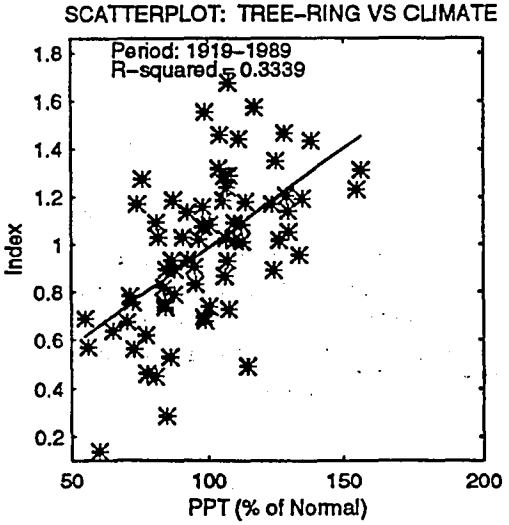
	State	ID	Distance (km)
MURDO	SD	39055891	45
COTTONWOOD 2E	SD	39051972	72
MERRIMAN	NE	25025470	89

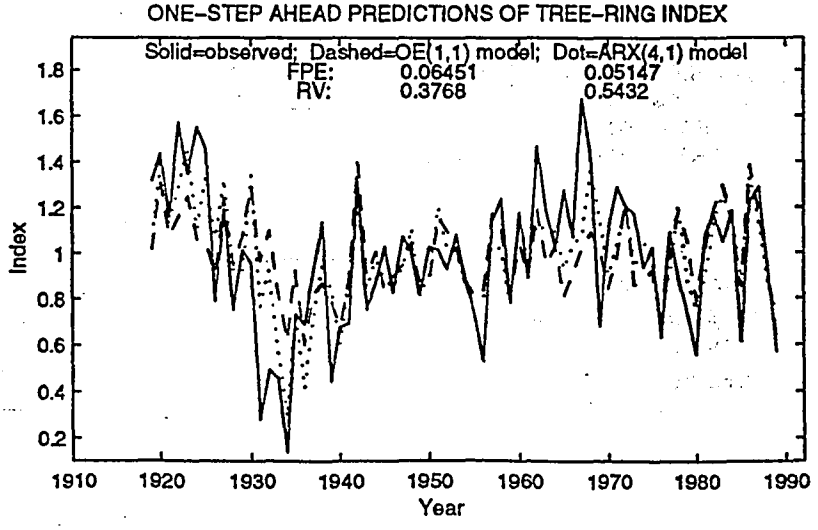












24 HRM Lake Herman State Park SD

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1740	133	59	51	67	76	80	40	26	27	57	1	1	1	1	1	1	1	1	1	1
1750	21	13	41	30	29	99	46	139	120	162	1	1	1	1	1	1	1	1	1	1
1760	78	266	225	145	136	149	51	85	57	38	1	1	1	1	1	1	1	1	1	1
1770	53	22	24	18	27	100	123	197	223	114	1	1	1	1	1	1	1	1	1	1
1780	141	112	59	193	225	178	215	189	214	181	1	1	1	1	1	1	1	1	1	1
1790	256	115	116	259	195	74	128	154	176	169	1	1	1	1	1	1	1	1	1	1
1800	47	158	123	87	91	149	162	159	131	87	1	1	1	1	1	1	1	1	1	1
1810	137	112	106	91	71	69	56	60	58	86	1	2	2	2	2	2	2	2	2	2
1820	71	88	69	53	71	121	178	132	93	63	2	2	2	2	2	2	2	2	2	3
1830	58	56	52	73	53	46	67	122	79	52	3	3	3	3	3	3	3	3	3	3
1840	100	75	49	71	96	72	51	36	39	55	3	3	3	3	4	4	4	4	4	4
1850	112	119	109	150	126	107	132	108	108	112	4	4	4	4	4	4	4	4	4	4
1860	94	117	133	104	69	106	112	140	96	125	4	4	4	4	4	4	4	4	4	4
1870	131	76	109	132	101	128	124	131	106	88	5	6	6	7	7	7	7	7	7	7
1880	90	124	126	105	142	129	71	84	102	65	7	7	7	7	7	7	7	7	7	7
1890	64	67	84	58	48	51	91	128	138	95	7	7	7	7	8	9	9	9	9	9
1900	64	111	104	154	136	127	106	119	131	103	9	9	9	9	9	9	9	9	9	9
1910	83	59	121	114	109	114	123	87	71	114	9	9	9	9	9	9	9	9	9	9
1920	119	81	100	71	76	49	40	100	76	96	9	9	9	9	9	9	9	9	9	9
1930	77	42	82	62	48	74	63	50	58	48	8	8	8	8	8	8	8	8	8	8
1940	53	62	121	92	130	123	71	116	105	84	8	8	8	8	8	8	8	8	8	8
1950	83	100	91	113	91	63	125	136	107	73	8	8	8	8	8	8	8	8	8	8
1960	108	101	85	66	97	116	93	96	98	108	8	8	8	8	8	8	8	8	8	8
1970	117	88	147	104	109	110	77	90	132	149	8	8	8	8	8	8	8	8	8	8
1980	118	87	115	120	117	104	120	100	94	82	8	8	8	8	8	8	8	8	8	8
1990	113	101									8	8								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: HRM.RWL
13 SERIES IN FILE, 4 NOT USED
CORE MASK: 1234567890123
0101100121212
DEFAULT FIRST CURVE FIT: LEAST-SQUARE-FIT STRAIGHT LINE
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH THE MEAN
2 SPECIAL (NON-DEFAULT) CURVE FITS
9 CORES, 6 TREES IN FINAL CHRONOLOGY

REMARKS

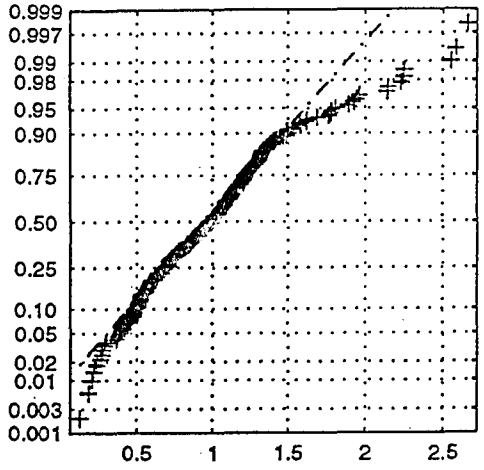
Lake Herman State Park, in southeastern South Dakota, 8 km southwest of Madison, South Dakota. This site is a flat mowed area near picnic grounds on the shores of glacial Lake Herman. An old homestead here had been converted into a state park in 1946. The oldest tree (inner ring, 1740) grows about 75 m north of the lake. This tree has a double trunk -- each trunk with a diameter of about 60 cm -- and a full, spreading crown. Centers of most of the oaks cored are rotten. Three cores were also taken from the nearby Herman Luce cabin, built in 1871. These cores have too few rings to establish crossdating with the living chronology.

LAKE HERMAN STATE PARK

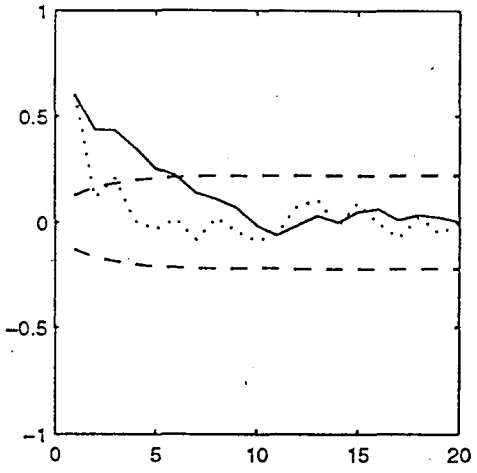
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
FORESTBURG 3NE	SD	39073029	72
CANTON 4WNW	SD	39091392	86
MENNO	SD	39095481	90

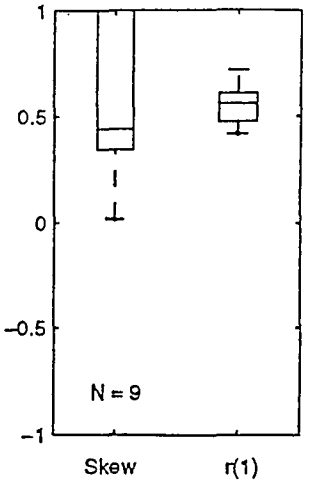
Normal Probability Plot



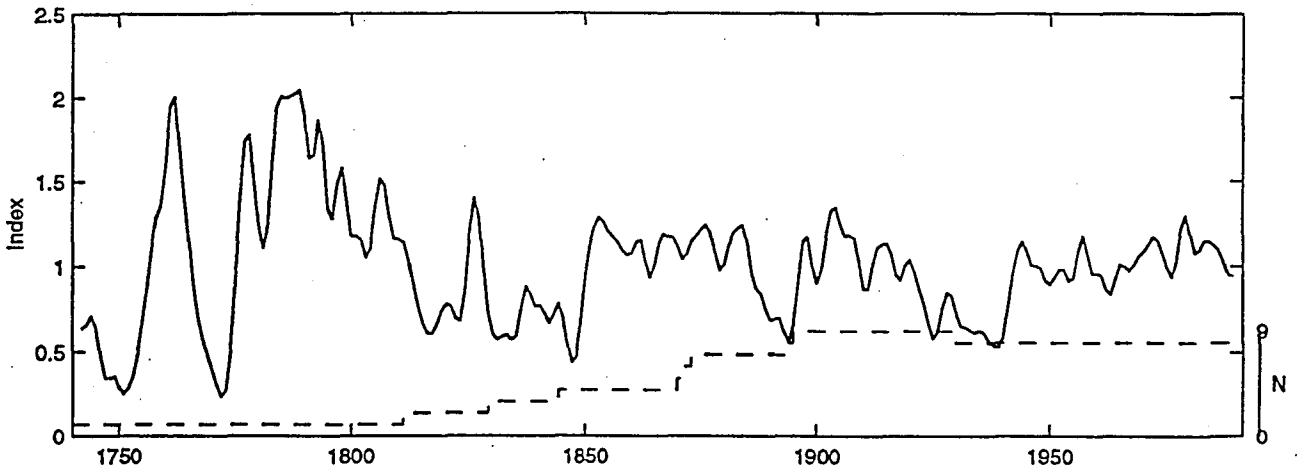
ACF (solid) and PACF (dot)



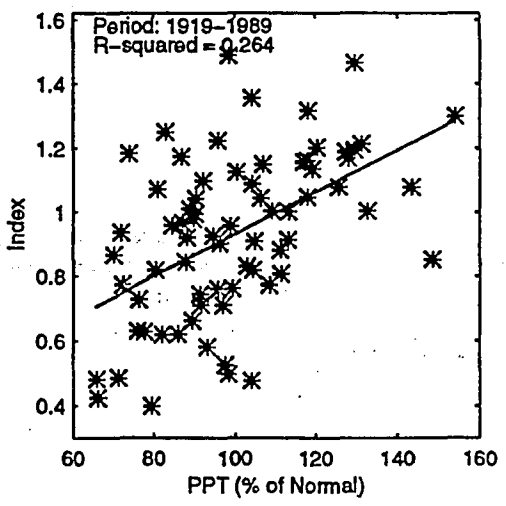
CORE INDICES



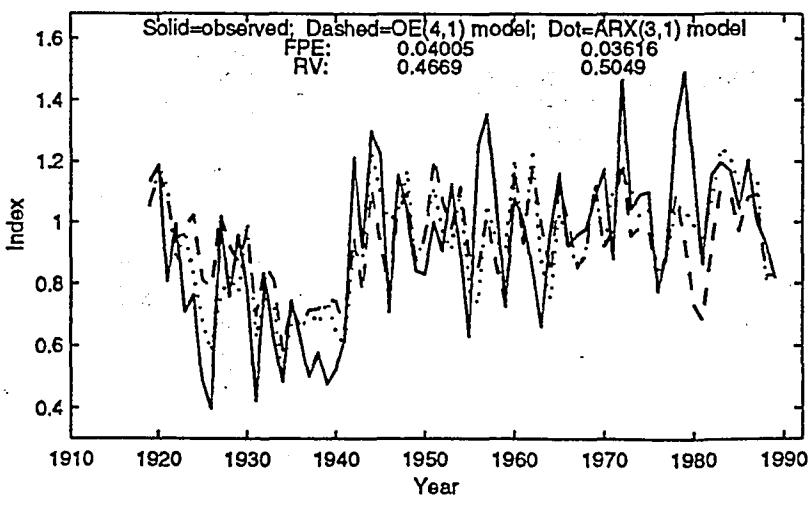
SMOOTHED TREE-RING INDEX, 1742-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



25 ORL Orland Hutterite Colony SD

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1859										33
1860	77	81	67	38	45	36	50	77	97	101
1870	107	63	65	66	117	208	88	95	258	142
1880	139	187	103	102	79	73	61	67	60	50
1890	50	63	78	84	54	49	69	74	106	112
1900	78	139	137	155	128	148	124	102	123	123
1910	100	78	138	136	79	90	142	117	116	147
1920	149	98	108	89	110	80	60	122	102	111
1930	102	63	100	68	50	96	75	73	68	49
1940	73	101	156	97	165	176	71	116	112	105
1950	89	160	115	109	101	78	77	128	85	63
1960	113	111	125	83	107	123	86	122	88	120
1970	118	97	156	112	109	110	73	80	122	152
1980	104	85	128	123	121	69	86	92	79	78
1990	104	112								

Number of samples

0	1	2	3	4	5	6	7	8	9
									1
1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1
1	1	1	2	2	2	2	2	3	3
3	4	5	6	8	8	8	8	9	9
11	11	12	14	15	15	15	17	17	17
19	19	19	19	19	19	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20								

CHRONOLOGY MAKEUP

RING-WIDTH FILE: ORL.RWL
20 SERIES IN FILE, 0 NOT USED
CORE MASK: 12345678901234567890
12121212121212121212
DEFAULT FIRST CURVE FIT: STRAIGHT LINE BY LINEAR REGRESSION
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH THE MEAN
2 SPECIAL (NON-DEFAULT) CURVE FITS
20 CORES, 10 TREES IN FINAL CHRONOLOGY

REMARKS

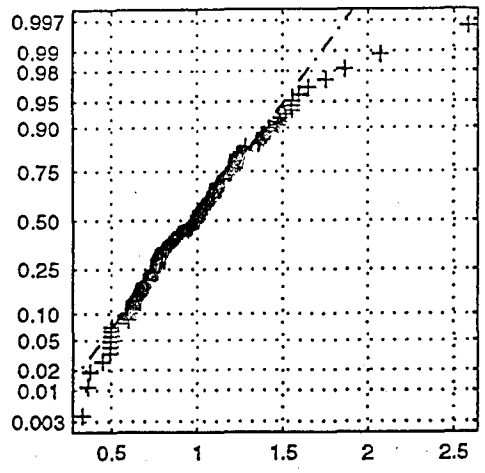
Private land in southeastern South Dakota, 16 km northwest of Montrose, South Dakota. Chronology species -- bur oak. Samples are mainly from north-facing slopes above a small tributary of the Vermillion River. Slope angles range from gentle to about 45 degrees. The south-facing exposures are devoid of trees. A dense understory of shrubs surrounds most trees. The oldest sampled tree (inner ring, 1883) is also the smallest-diameter (34 cm) tree cored. This tree is growing in the open on a 20-degree northwest-facing slope near the top of a hill.

ORLAND HUTTERITE COLONY

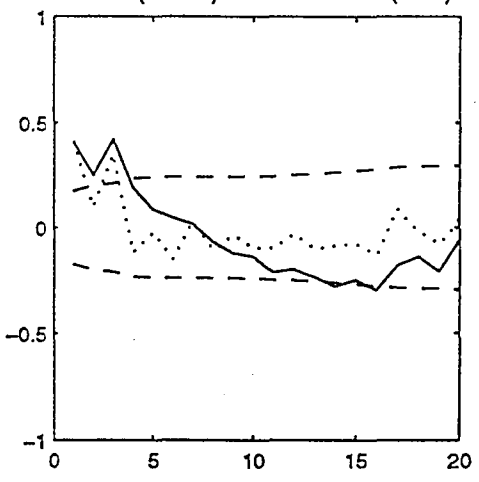
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
CANTON 4WNW	SD	39031392	69
MENNO	SD	39095461	81
FORESTBURG 3NE	SD	39073029	84

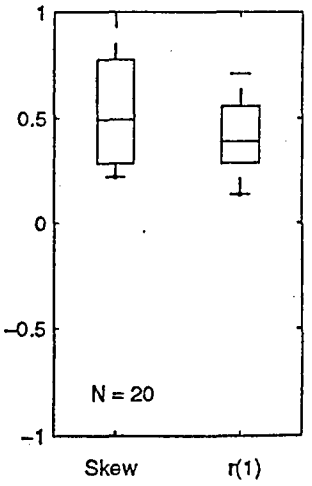
Normal Probability Plot



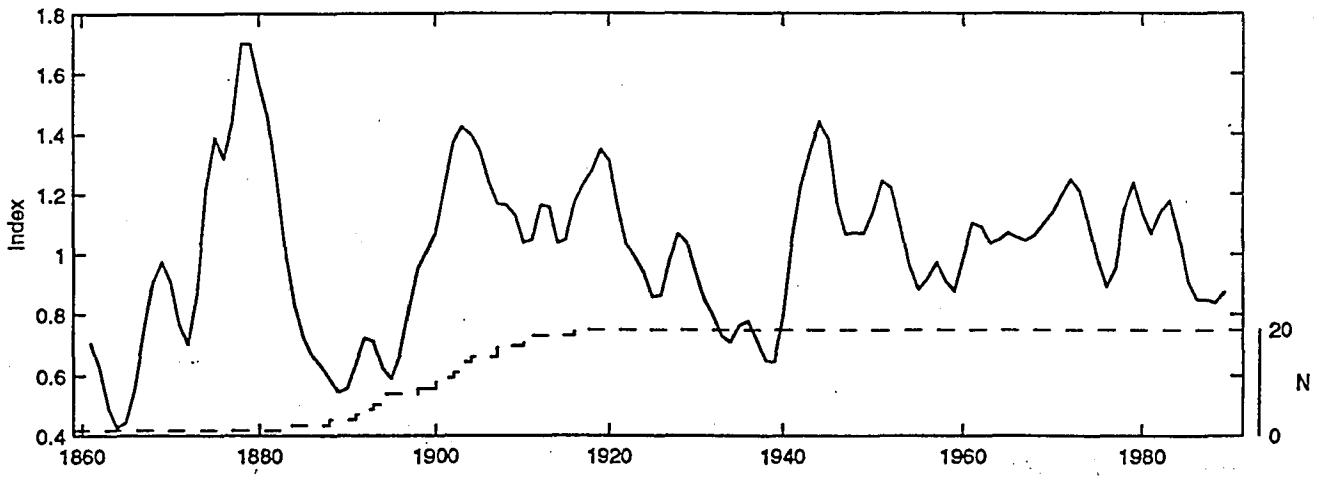
ACF (solid) and PACF (dot)



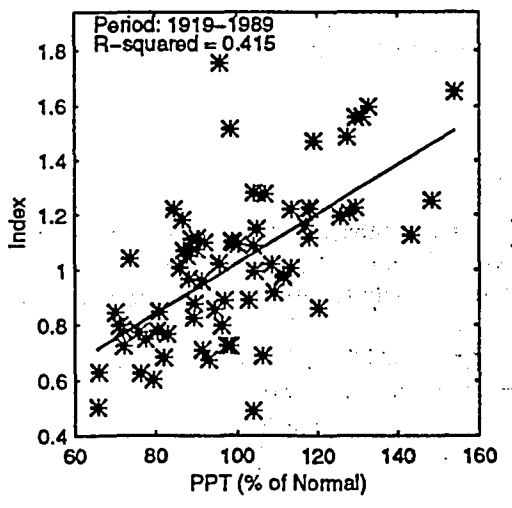
CORE INDICES



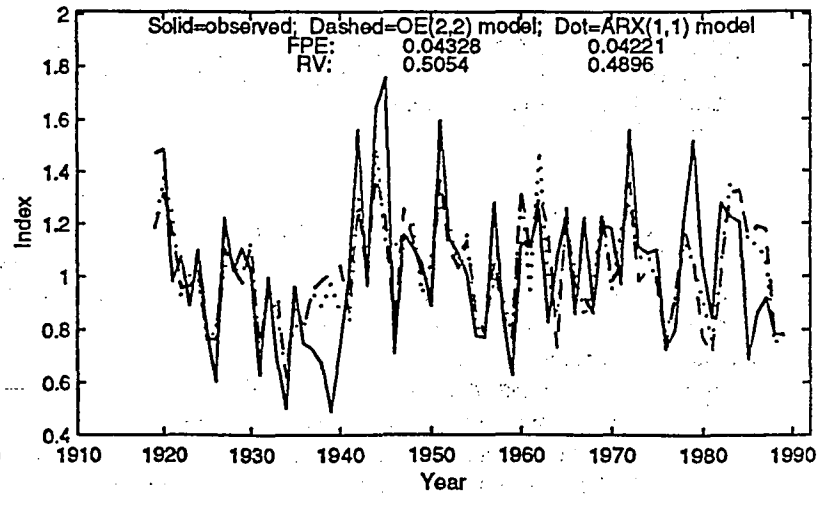
SMOOTHED TREE-RING INDEX, 1861-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



26 ICE Icelandic State Park ND

	Tree-Ring Indices										Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1830	235	184	184	129	121	161	83	65	71	43	2	2	2	2	2	2	3	3	3	3
1840	77	114	64	82	66	61	118	104	93	128	3	3	3	3	3	3	3	3	3	3
1850	96	109	117	90	100	70	89	109	107	87	3	3	3	3	3	3	3	3	3	3
1860	133	114	119	99	81	92	112	92	111	63	3	4	4	4	4	4	4	4	4	4
1870	64	55	74	99	95	104	98	135	87	104	4	4	4	4	4	4	4	5	5	5
1880	115	84	90	72	94	109	86	84	89	62	5	5	5	5	5	5	5	5	5	5
1890	81	97	101	105	97	80	114	82	99	98	5	5	5	5	5	6	6	7	7	7
1900	71	117	128	107	121	122	102	109	91	111	7	7	7	7	8	8	8	8	8	8
1910	86	107	125	108	107	75	122	61	96	109	8	8	8	8	8	8	8	8	8	8
1920	106	109	144	125	102	106	104	104	93	93	8	8	8	8	8	8	8	8	8	8
1930	83	88	98	108	97	113	93	108	110	91	8	8	8	8	8	8	8	8	8	8
1940	115	119	128	99	94	121	53	82	101	65	8	8	8	8	8	8	8	8	8	8
1950	97	92	100	125	86	79	98	110	94	96	8	8	8	8	8	8	8	8	8	8
1960	85	78	87	109	83	95	99	90	101	97	8	8	8	8	8	8	8	8	8	8
1970	110	112	98	116	102	105	102	109	122	105	8	8	8	8	8	8	8	8	8	8
1980	95	107	108	85	92	96	125	92	94	100	8	8	8	8	8	8	8	8	8	8
1990	101	85	89								8	8	7							

CHRONOLOGY MAKEUP

RING-WIDTH FILE: ICE.RWL
8 SERIES IN FILE, 0 NOT USED
CORE MASK: 12345678
12121211
DEFAULT FIRST CURVE FIT: SPLINE WITH 0.5 FREQUENCY RESPONSE AT WAVELENGTH OF 100 YR
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH THE MEAN
1 SPECIAL (NON-DEFAULT) CURVE FITS
8 CORES, 5 TREES IN FINAL CHRONOLOGY

REMARKS

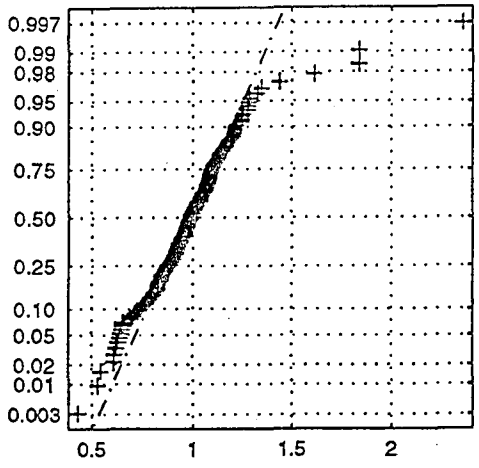
State Park land in the northeastern corner of North Dakota, 40 km southwest of Pembina, North Dakota. Chronology species -- bur oak. This site, the Gunlogson Historic Homestead - Wildwood Trail, is a boggy area surrounded by Tongue River on the south and slightly higher elevation (300 m) to the north. The hills are covered with bur oak, but the trees are small and many are rotten at the center. Homesteading in the mid-1800s. G. B. Gunlogson reportedly harvested all the trees in the area and protected most of the farm from logging. He cleared some areas for farming -- currently these are vegetated pastures. Trees in the bogs may have been spared from logging only because of the difficulty getting them out and over the steep river banks. The oldest sampled tree has an inner dated ring of 1830 and about 50 additional undated rings containing a severe growth suppression in the 1820s. This tree is 23 m tall, has a diameter of 74 cm, and is growing on a forested lowland site.

ICELANDIC STATE PARK

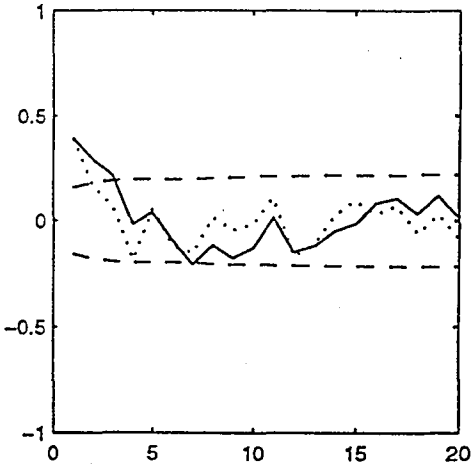
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
LANGDON EXPERIME	ND	32034958	43
PEMBINA	ND	32036947	44
GRAFTON	ND	32033594	46

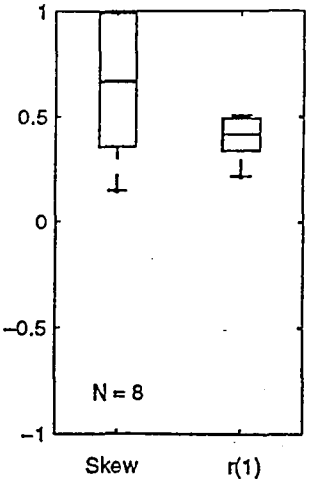
Normal Probability Plot



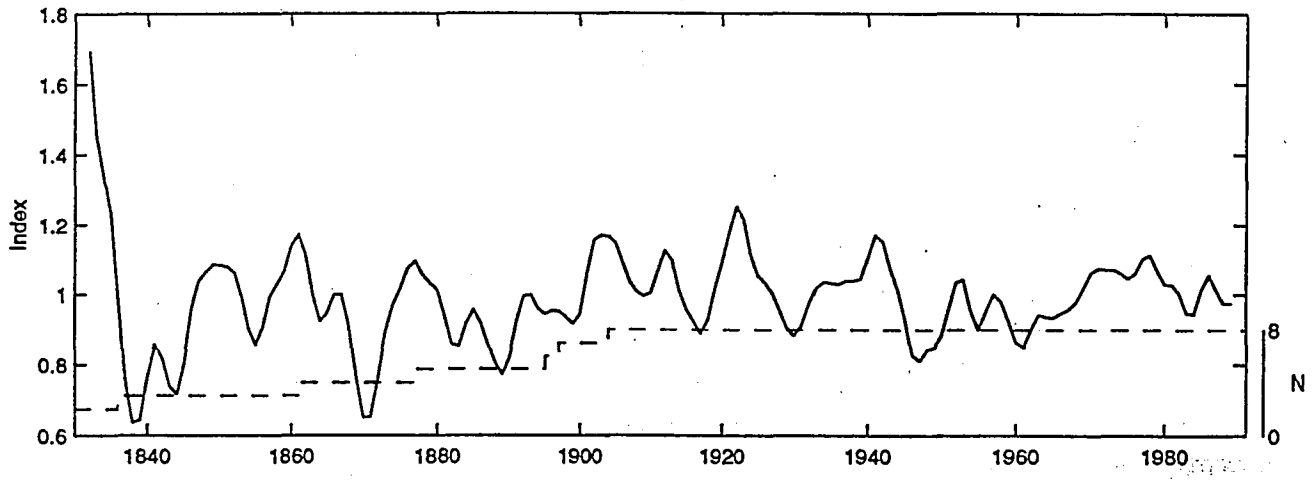
ACF (solid) and PACF (dot)



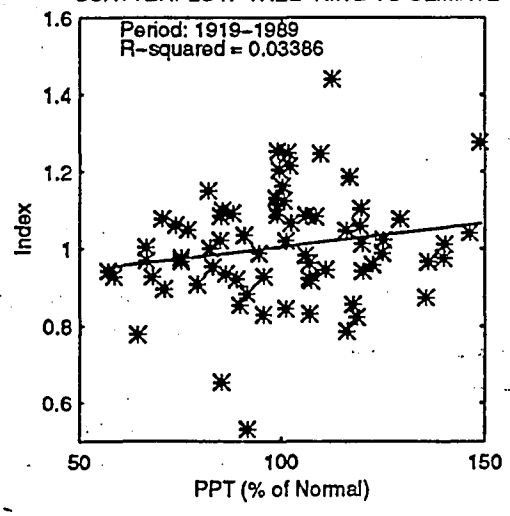
CORE INDICES



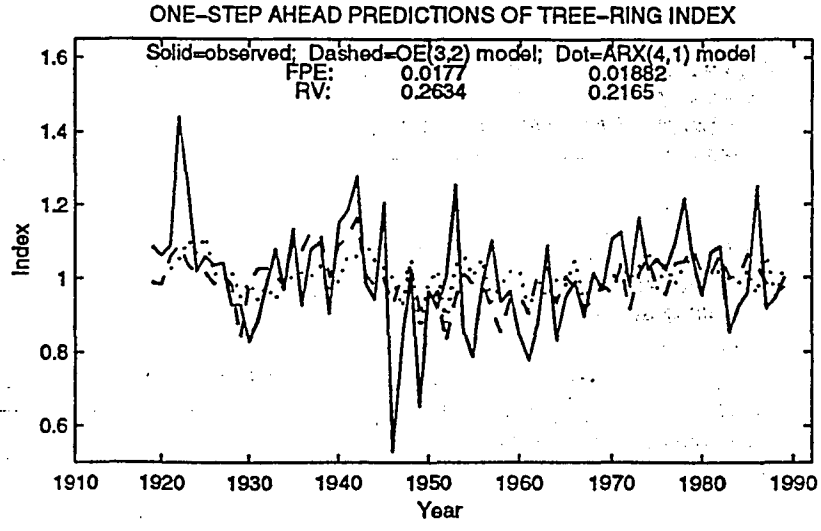
SMOOTHED TREE-RING INDEX, 1832-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



27 PEM Pembina Hills ND

Tree-Ring Indices

Date	0	1	2	3	4	5	6	7	8	9
1831		93	61	66	104	58	28	24	66	107
1840	97	83	83	88	62	46	103	94	103	39
1850	45	77	151	159	129	72	120	105	126	105
1860	156	61	117	99	24	46	68	77	96	48
1870	85	85	90	103	120	113	142	168	83	80
1880	102	125	118	79	92	123	92	105	123	82
1890	119	140	157	157	120	101	140	121	142	140
1900	80	124	123	97	141	140	116	122	105	135
1910	83	115	125	106	104	86	115	84	92	97
1920	105	108	102	113	92	97	80	100	98	82
1930	80	74	78	86	61	99	69	101	76	62
1940	66	98	111	90	78	107	69	99	113	109
1950	116	82	78	106	101	105	107	127	92	88
1960	84	74	95	119	103	117	105	93	127	135
1970	141	109	96	117	110	129	95	128	150	131
1980	81	99	132	104	90	98	133	107	87	103
1990	100	92	96							

Number of samples

0	1	2	3	4	5	6	7	8	9
	1	1	1	1	1	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	2	2	2	2	2	2	2
2	2	2	3	3	3	3	3	3	4
4	4	4	4	4	4	4	4	4	5
6	6	8	8	9	10	11	11	11	11
12	12	12	12	12	13	14	14	14	14
16	16	16	16	16	17	18	18	18	19
19	19	19	19	19	19	19	19	19	19
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20
20	20	20							

CHRONOLOGY MAKEUP

RING-WIDTH FILE: PEM.RWL
20 SERIES IN FILE, 0 NOT USED
CORE MASK: 12345678901234567890
12121212121212121212
DEFAULT FIRST CURVE FIT: STRAIGHT LINE BY LINEAR REGRESSION
DEFAULT SECOND CURVE FIT: HORIZONTAL LINE THROUGH THE MEAN
1 SPECIAL (NON-DEFAULT) CURVE FITS
20 CORES, 10 TREES IN FINAL CHRONOLOGY

REMARKS

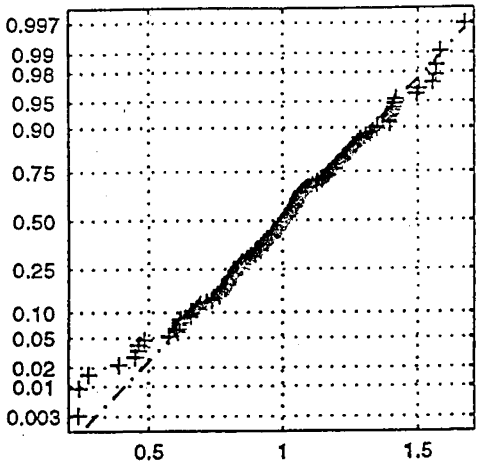
Northeastern corner of North Dakota, centered about 24 km west of Pembina, North Dakota. Chronology species -- bur oak. Large oaks are extremely rare in this region. Farms are huge with little unplowed area. Logging has decimated the natural stands of trees; present woodlots used as wind breaks are natural regeneration. Pembina was the location of the first homesteaders in the 1800s. After being flood victims of the Red River, the settlers moved west to the Walhalla area -- Pembina Hills. Fur trappers and traders first settled the Walhalla area 150 years ago. Photos taken in 1899-1901 show the hills devoid of trees because of major logging. The samples were collected during a widespread two-day search. The oldest sample (inner ring, 1831) is from just southeast of the Middle Branch of Park River, in Walsh County. This tree has a diameter of 62 cm, and is growing on flat ground in deep black soils in a fairly open woodlot.

PEMBINA HILLS

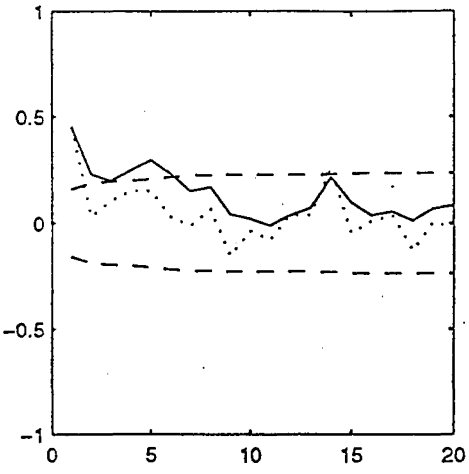
Climate Stations and Distances to Tree-Ring Site:

	State	ID	Distance (km)
PEMBINA	ND	32036947	20
HALLOCK	MN	21013455	44
GRAFTON	ND	32033594	56

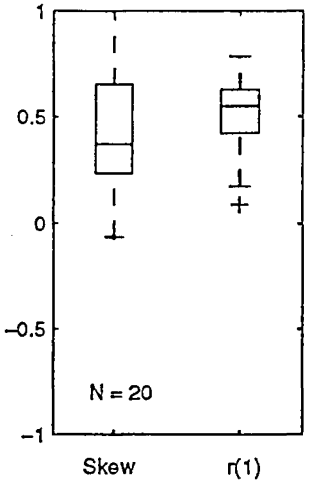
Normal Probability Plot



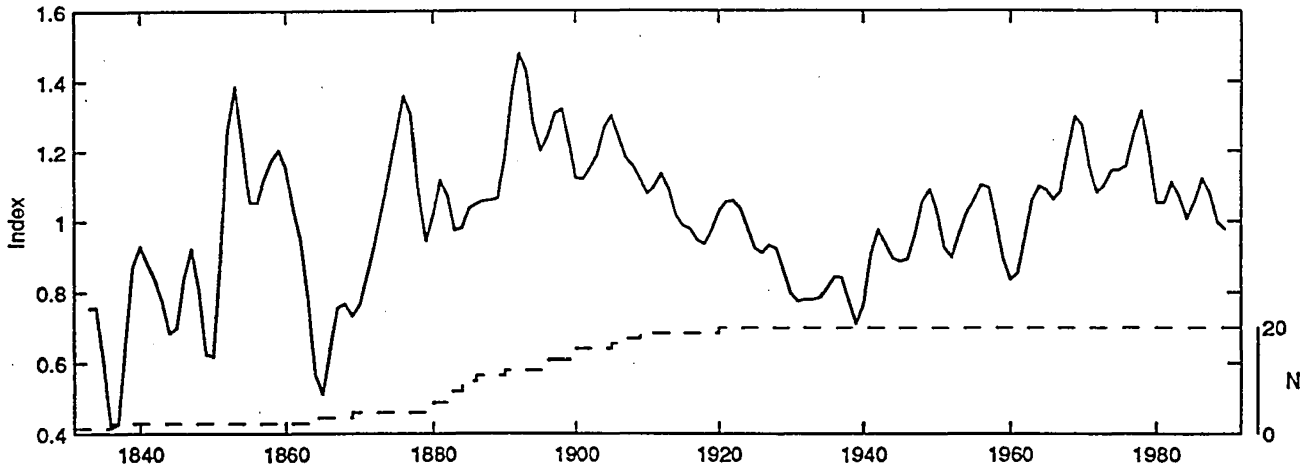
ACF (solid) and PACF (dot)



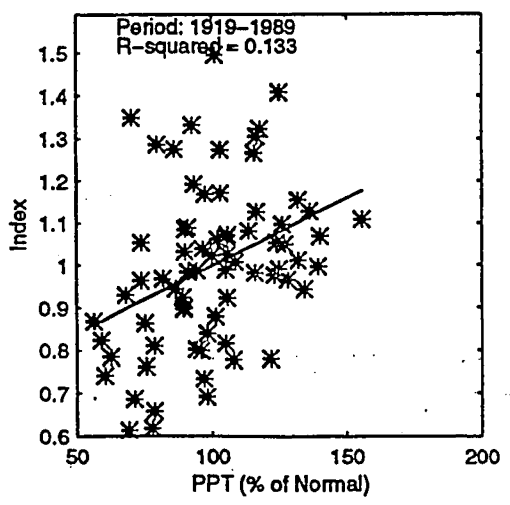
CORE INDICES



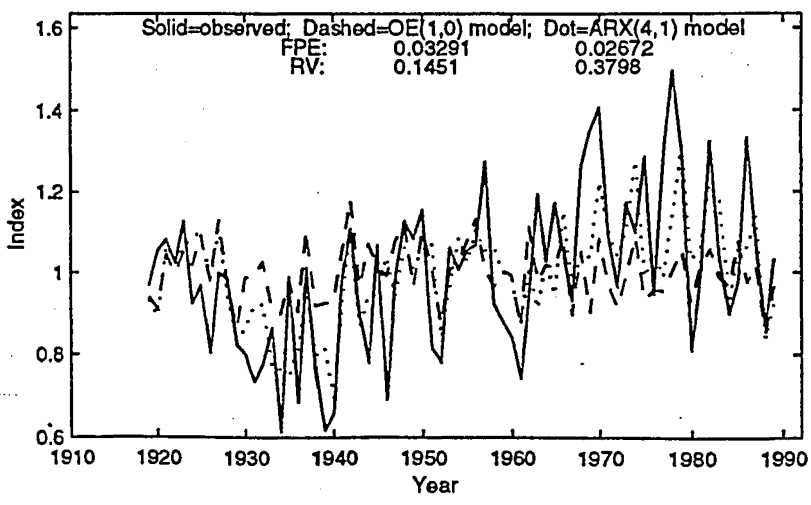
SMOOTHED TREE-RING INDEX, 1833-1989; SAMPLE SIZE WITH SCALE AT RIGHT



SCATTERPLOT: TREE-RING VS CLIMATE



ONE-STEP AHEAD PREDICTIONS OF TREE-RING INDEX



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Appendix A. Contents of Diskette

Data files for the chronologies are available upon request on a 3 1/2", 1.44 MB diskette from David Meko for the cost of the diskette and mailing expenses. A subset of the chronologies is also being submitted to the International Tree-Ring Data Bank (ITRDB), in Boulder, Colorado. The chronologies in the ITRDB might differ than those on the diskette reported here because of additional steps in processing. For example, the cores from Pembina Hills and Icelandic State Park are being combined in a single "Pembina Hills Merged" chronology to increase the sample size before being submitted to the ITRDB. The user of the chronologies is advised to obtain a copy of this report and also to read the text description in the ITRDB database for details about the relationship of the ITRDB chronologies to the basic data described here.

The data diskette for this report can be obtained from David Meko at the following address:

Laboratory of Tree-Ring Research
University of Arizona
Tucson, AZ 95721

Phone: (520) 621-2457
-8229 (fax)
Email: dmeko@ccit.arizona.edu

Various files for each chronology listed in Table 2 (page 19) have been compressed into a self-expanding file using PKWARE Inc.'s PKZIP software. A chronologies files are stored in the executable file XXX.EXE, where XXX is the chronology code in Table 2. The files can be expanded simply by making the directory storing the XXX.EXE the current directory and typing XXX at the DOS prompt. For example, files for the Custer State Park chronology can be expanded by typing "CSP". The following files have been stored for each chronology. Substitute the appropriate chronology code for XXX:

XXX.STD -- standard site chronology. The format is identical to that required for chronologies submitted to the International Tree-Ring Data Bank (Grissino-Mayer et al. 1992). A three-line header with information on site location, species, time-coverage and principal investigators is followed by one line per decade with the chronology values and sample size (number of cores) and sample size for each year). Refer to Grissino Mayer et al. (1992) for details.

XXX.RES -- residual site chronology. Format is identical as for XXX.STD. Header-line content will generally differ from that of XXX.STD in that (1) beginning year is later because of loss of one or more years of leading data in generating autoregressive residuals, and (2) an "R" appears on line 3 rather than a blank space in the column directly below the second letter of the species code.

XXX.RWL -- ring-width measurements. This file was used as input to program ARSTAN (see text) in generating the chronology. Data are in "rwl" format as described by Grissino-Mayer et al. (1992).

XXX.SCR -- ARSTAN input-control. ARSTAN was run in a batch mode using a script file containing all selections of model options. This approach was convenient in chronology development in that it was not necessary to re-key in all settings for ARSTAN just to change a few options -- for example, to truncate a ring-width series years of juvenile growth. A second convenience is that the script file is a record of ring-width series deleted, curve options used , etc., in chronology development. A third convenience is that an independent researcher with access to program ARSTAN can duplicate our work very easily. Assuming that paths to program files and data files are properly set, all that is necessary is to type the following command at the DOS prompt:

ARSTAN<XXX

where the chronology code should be substituted for XXX. The command above will start the executable ARSTAN program, piping in the lines from XXX.SCR as if those lines had been keyed in one by one in response to ARSTAN prompts.

Appendix B. Reno Gulch Standard Chronology -- 1281-1599

The entire Reno Gulch chronology was too long for listing in the two-page format of the chronology snapshot pages of this report. The 1281-1599 portion is listed below. The 1600-1991 portion is listed on page 64.

Tree-Ring Indices											Number of samples									
Date	0	1	2	3	4	5	6	7	8	9	0	1	2	3	4	5	6	7	8	9
1281		228	316	93	149	162	221	144	215	246		1	1	1	1	1	1	1	1	1
1290	183	169	198	208	201	253	140	142	94	114	1	1	1	1	1	1	1	1	1	1
1300	94	75	108	162	133	80	72	96	104	104	1	1	1	1	1	1	1	1	1	1
1310	104	119	119	139	138	106	49	114	109	60	1	1	1	1	1	1	1	1	1	1
1320	87	74	101	165	108	85	55	71	21	15	1	1	1	1	1	1	1	1	1	1
1330	32	38	47	34	60	70	32	60	64	64	1	1	1	1	1	1	1	1	1	1
1340	30	7	28	69	95	134	78	87	46	61	1	1	1	1	1	1	1	1	1	1
1350	72	70	83	59	79	103	82	88	95	58	1	1	1	1	1	1	1	1	1	1
1360	12	58	62	138	125	25	22	107	90	112	1	1	1	1	1	1	2	2	2	2
1370	140	99	68	66	97	126	107	58	51	58	2	2	2	2	2	2	2	2	2	2
1380	66	93	69	78	90	80	87	87	61	114	2	2	2	2	2	2	2	2	2	2
1390	54	106	78	28	60	64	101	70	62	47	2	2	2	3	3	3	3	3	3	3
1400	64	37	64	69	89	96	67	37	37	71	3	3	3	3	3	3	3	3	3	3
1410	81	94	99	90	145	85	75	138	118	92	3	3	3	3	3	3	3	3	3	3
1420	83	88	47	65	70	127	136	97	72	102	3	3	3	3	3	3	3	3	4	4
1430	110	165	163	123	130	137	126	113	173	144	4	4	4	4	4	4	4	4	4	4
1440	153	222	203	183	114	182	158	126	128	93	4	4	4	4	4	4	4	4	4	4
1450	120	101	113	156	171	103	102	104	103	84	4	4	4	4	4	4	4	4	4	4
1460	56	65	73	72	92	102	99	65	67	63	4	4	4	4	4	4	4	4	4	4
1470	63	85	66	136	107	101	98	95	116	77	4	4	4	4	4	4	4	4	4	4
1480	90	99	81	102	109	105	64	79	108	29	4	4	4	4	4	4	4	4	4	4
1490	71	107	71	77	101	87	71	106	140	113	4	4	4	4	4	4	4	4	4	4
1500	112	79	91	77	118	113	75	78	82	98	4	4	4	4	4	4	4	4	4	4
1510	65	120	129	57	120	116	117	122	144	124	4	4	4	4	4	4	4	4	4	4
1520	94	111	111	114	146	125	106	125	71	92	4	4	4	4	4	4	4	4	4	4
1530	104	96	72	65	43	62	67	85	72	60	4	4	4	4	4	4	4	4	4	4
1540	73	71	48	67	55	51	65	40	52	89	4	4	4	4	4	4	4	4	4	4
1550	83	81	104	92	76	86	81	92	71	120	4	4	4	4	4	4	4	4	4	4
1560	135	125	162	122	124	136	166	130	149	157	4	4	4	4	4	4	4	4	4	4
1570	137	157	156	122	128	86	95	113	117	123	4	4	4	4	4	4	4	4	4	4
1580	55	74	73	107	145	124	82	134	109	117	4	4	4	4	4	4	4	4	4	4
1590	80	33	79	80	82	98	58	82	89	116	4	4	4	4	4	4	4	5	5	5